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WHAT DO YOU KNOW ABOUT TEKTITES?

G. G. Vorob'yev

Translation of "Chto Vy Znayete o Tektitakh?"
Moscow, "Nauka" Press, 1966, 112 pages

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16. Abstract

The discovery and geographical distribution of tektites is presented and analyzed in this popular account of tektites. Uses made of tektites by ancient and present-day peoples are examined as possibly indicative of tektite origins. The various theories on the origin of tektites are weighed. Field collection of tektites in South Czechoslovakia is described. The rise and waning and revival of interest in tektites is traced. Tektite strewnfields are delineated and related to possible impacts of asteroids or lunar material on the earth.

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ANNOTATION

Can cosmic bodies fall on the earth? Old-fashioned science persistently denied this until a meteor shower fell in France at the beginning of the 17th century. Until recently many doubted the cosmic origin of tektites -- unusual glasses encountered in different parts of the earth.

From time to time tektites have been found on the earth in abundant beds, covering territories of millions of square kilometers. How they occurred is as yet unknown. Perhaps, these are particles of disintegrated planets, lava of lunar volcanoes, the products of meteoritic or comet explosions on the earth or the moon.

Many scientists have participated in puzzling out the cosmic origin of tektites -- astronomers, physicists and mathematicians, chemists and technologists, geologists and archaeologists, and specialists in explosions, ballistics, and aerodynamics.

Tektites have not yet been found in our country.

The aim of this book is to attract even more investigators to the study of tektites and promote new tektite finds.

/FOREWORD/

/3

Before me are three scientific articles. They were published in different journals, in different languages, and at different times. But their headings are the same:

L'ENIGME DES TECTITES/ ZAHADA TEKTITU/ ZAGADKA TEKTITOV

What are tektites? What does the mystery consist of? Ten years ago I, just as many of us, knew nothing about this. There passed years of searching through libraries and archives, painstaking laboratory work, fascinating hikes, correspondence with colleagues, and heated discussions at encounters. Now I can recount all that became known during this time.

The aim of this book is not only to familiarize the curious reader with a little-known scientific problem that has not yet lost the flavor of romanticism. Another goal is even more important: to enlist in the study of tektites new volunteers -- representatives of various disciplines, to summon participants of expeditions, students of local lore, and tourists to systematic efforts to find tektites in our country.

One of the difficulties of the tektite problem is that a number of scientific disciplines are curiously interwoven here -- astronomy and geology, chemistry and physics, ballistics and aerodynamics, ethnography and archaeology, mathematics and cybernetics.

Representatives of each of these sciences have enriched the common storehouse of knowledge with valuable facts, however they have drawn conclusions from their own vantage point in the process. These conclusions as a rule are proved to be incorrect and have only obscured the matter. Unified efforts of scientists from different disciplines and different countries are needed in order to approach the solution of the problem.

I am a geochemist, therefore the book to some extent has been /4
written from the viewpoint of my science, though I have been also given the aim of imparting an overall scope to the book.

My friendship with scientists and students in Czechoslovakia aided in obtaining some materials on tektites.

Therefore to them --

to my wonderful Czech friends,
I dedicate this book.

Moscow -- Ceske-Budejovice,
April 1965

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WHAT DO YOU KNOW ABOUT TEKTITES?

G. G. Vorob'yev

PUZZLE OF CZECH GLASS

Trailblazer -- Primitive Man. -- "Bottle Glass." -- Geologists, Chemists, Archaeologists, and Astronomers Argue. -- Instructive Curiosity

Europe, 25,000 years ago. People of the Stone Age are gradually populating the continent, moving from south to north. Many hundreds of kilometers are covered by their encampments. In search for prey hunters abandoned their homes for long periods of time. But they are interested not only in hunting. They seek a stone -- a beautiful, strong, and easily workable stone. From it they make axes, knives, and arrowheads.

Pieces of a dark-green glassy stone was found in the vicinity of Dunay at one such encampment. Here an inexperienced person would have taken them to be ordinary bottle glass. But this is what would have appeared only at first glance. The stone took grinding well, was amazingly strong, and only after a very strong blow did it shatter into small fragments. Primitive man valued it and found useful in his simple economy.

The Czech Lands of the 17th century. This very small region, now called Bohemia, was part of the Austrian monarchy.

How amazingly beautiful is the South Czech landscape! Spruce forests and groves alternate with meadows and plowlands. Clouds fleeting along the sky are reflected in quiet little streams and pensive lakes -- "fish ponds".

The River Moldau (Vltava) runs through the South Czech lands. It begins in the Shumava mountains, densely overgrown with leafy verdure, now nearly blue in the early chilly morning, now emerald in the rays of the noontime sun, and black at sunset and on the infrequent overcast days. The Vltava is capricious -- it bubbles over the rapids, meanders, and spreads out broadly, forming quiet backwaters with picturesque nooks.

Medieval castles can be seen from afar on high hills: Ceske-Krumlov, Zlate-Koruna, and Gluboka.

Literally at each step there are hamlets with sonorous names: /6
Slavche, Divchitse, Malovitse, Lochenitse, Lipi, ...

The populace is engaged in farming, orchardry, and fisheries. Sometimes they find lovely green stones in their fields. If they facet them, a rich, pure color and strong glassy luster appear. The stones are eagerly used for necklaces and other trinkets.

Gradually these stones reach the marketplace, where in contrast to semiprecious minerals and rocks similar to them -- chrysolites[1], garnets [2], and obsidians [3], they began to be called pseudo, Bohemian, or water (that is, pure) chrysolites, chrysolitoids, or glassy obsidians, or simply bottle stone.

Then, the attention of scientists was directed to these strange glasses. The first reliable report on them dates to 1788, when a certain Josef Mayer wrote in one of the Bohemian journals for naturalists: "Lovely fragments of green glass masses have been often found in the area of Teyn on the Moldau, equal in hardness to garnets, very pure and translucent, usually with a beautiful dark-green color, and marketed as chrysolites. I did not observe them to exhibit any form other than amorphous in the shape of round pebbles and small boulders; and now they are encountered only in these forms in scattered detritus in fields and eroded rain gullies. The size of the detrital fragments often exceeds a hen's egg, and settings for canes 1 inch wide to 2 inches long can be cut from some specimens."

Further study showed that these glasses can be encountered in river and lake sediments, and also in native rocks -- sands. Typical of them are rounded and elongated, often convex-concave forms, and also complex figures of surficial structure ("sculptures"),

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[1] Chrysolite is a clear green variety of the mineral olivine (from the word "olive") -- a silicate of magnesium and iron.

[2] Garnets represent a group of minerals, silicates of various metals. Green garnet is called grossular ("grossularia" -- gooseberries).

[3] Obsidian is a volcanic glass (named after the Roman Obsius who brought this stone from Ethiopia).

resembling the paths of worms, and sometimes the kernel of a walnut, while other times blisters on inflamed skin (Fig. 1).

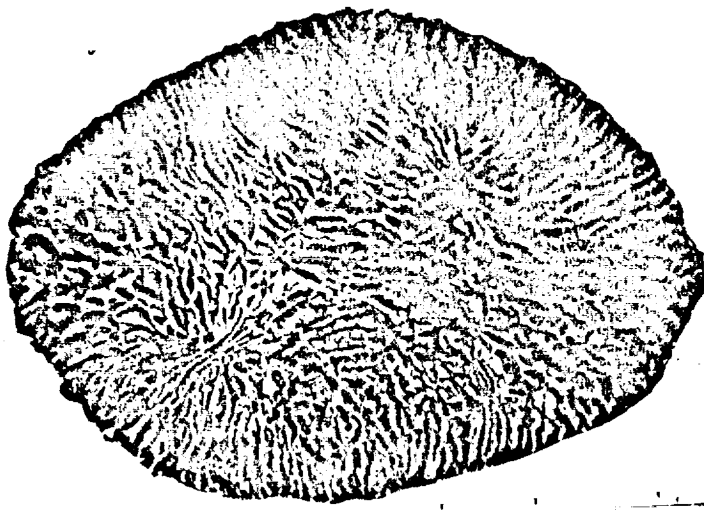

Fig. 1. Unique moldavite from Moravia, weighing 153 g (72 x 50 x 45 mm) /7

From the site of the discoveries they were given the name moldavites (vltaviny), which was extended also to later discoveries in Moravia -- an adjoining region separated from the South Czech Lands by the Czech-Moravian highlands.

Two tasks confront the scientists: to establish the place of moldavites in the general system of minerals and rocks and to determine the conditions of their formation.

Most disturbing of all was the fact that moldavites are completely devoid of crystalline structure typical of the vast majority of geological objects. Of the several thousand mineral species now known, only several have an amorphous state owing to solidification of water-saturated gels or the disintegration of the crystal lattice under the effect of radioactive rays. But further, these minerals crystallize spontaneously with time and, as shown by special experiments, they all contain elements (nuclei) of crystalline structure. Thus why the similarity of moldavites to garnets and chrysolites was only apparent.

It is somewhat more complicated to compare moldavites with obsidians. Obsidians are dark glasses formed in the rapid cooling of volcanic lava. They are quite diverse in composition, somewhat differing from the composition of moldavites, and if they are cooled in air during a volcanic eruption, then their form suggests /8
the form of moldavites. Old obsidians are partially crystallized and they all contain numerous mineral inclusions, which are not found in moldavites. Thus, moldavites, at first glance, are volcanic glasses, however detailed study returns "No's" every time. In addition, one must reckon with the principal argument: there are no volcanoes in Czechoslovakia, nor have there never been, at least at the location and at the time when tektite-bearing rocks were formed.

Thus, the first phase of the discussion on the origin of moldavites passed through these stages:

moldavites are special varieties of known minerals;

moldavites are volcanic glasses; and

moldavites are not minerals and they are not volcanic glasses.

But what then are they?

Thus began the second phase, very acute and engaging. Scientists proposed many hypotheses that were most improbable at first glance.

One of these came to be called the "carbon" hypothesis. As we know, carbon is capable of spontaneous combustion. This phenomenon is very often encountered in nature (stratal, coal fires), but has not yet been studied closely enough. Can we assume that under the effect of fire rock melted and moldavites were formed Geologists replied to this question in the negative: intervening rocks are of varied composition, and their products of fusion must also differ. In addition, fire does not produce the temperature required to melt such a "high-quality" glass as moldavites are essentially composed of.

Then a new hypothesis was born: perhaps, moldavites are products of an ancient glass industry? The culture of Czech (Bohemian) glass even at that time was quite advanced. Why could one not assume that it had deep historical roots? Ancient glassmakers labored over the technology of their articles, and then the workshop disappeared, and only traces of the mold materials and all kinds of glass cullet were left behind. And now the scientists racked their brains over the nature of these archaeological finds.

The first idea of the artificial origin of moldavites was expressed in 1792 by Johann Lindaker. But only a 100 years later /9
did the then-famous professor A. Makovskiy from the city of Brno present so brilliant arguments in favor of this hypothesis that several embarrassed geologists hastened to throw moldavites out of their mineralogical collections. The efforts of Makovskiy were directed fundamentally against the volcanic hypothesis, which the most stubborn skeptics had to finally abandon. But the problem of the artificial origin still required its own discussion.

At the close of the 19th century, especially heated debates raged on this subject. Czech and Austrian scientists fraternally criticized Makovskiy, pointing out that a pure glass such as moldavite is very difficult to make even now, not to speak of ancient times. Archaeologists denied the existence of ancient glassmaking plants at the sites of the finds, and where these plants were known, no moldavites were found. In addition, moldavites were discovered in beds of very ancient, prehistoric rivers.

Then there appeared an initially very bold hypothesis that tektites had arrived from outer space. Apparently A. Jegac was the first to write about this in 1898. Everything proceeded quite logically. If moldavites are not geological objects (at least, geologists have not been able to give any satisfactory terrestrial hypothesis) and they are not artificial (this is stated by archaeologists and chemists), this means that they are objects from outer space. But what then do the astronomers say about this?

The astronomers were not prepared for this discussion. Their science developed special, abstract approaches by virtue of the specific nature of their undertaking. In contrast with the scientists, they were not able to "probe" the objects of their investigations. Due to this, and also owing to the influence of the church, in general the probability of cosmic matter falling on the earth was denied. It was assumed that only enormous bodies are present in outer space. "Small bodies could not possibly be there!" asserted conventional science.

Even in 1794 the Czech scientist E. Chladni wrote the following on this matter: "However, there are few who are disposed to believe that the universe contains, besides large celestial bodies, many fine accumulations of gross material particles. But this disbelief is only apparent in nature and is based on no theory of any kind, but simply on prejudice.... Let us assume that someone asks: and how did these masses arise and how did they happen to be in such an isolated state?.... The most correct answer to this would be /10
the following: nothing definite can be given by way of answer to this question. Whatever hypotheses are advanced on this score, one of two must be admitted: either celestial bodies, whatever changes may have occurred on them or near their surface, have always been or will continue to be what they are today; or else in nature there exist forces sufficient to form celestial bodies or even entire celestial systems and also sufficient for their disintegration and for the construction of new bodies from the resulting material."

This excerpt returns us to the discussion on the cosmic nature of meteorites [4], which occurred a hundred years before the studies of Jegac. At that time meteorites, which were strongly distinguished by a long series of their properties from rocks, were already quite well known to science. Chladni wrote his book based on impressions he obtained in Petrograd on inspecting the famous meteorite Pallas Iron. Both scientists were hostile toward his ideas. They said that Chladni "denies the whole order of things and does not weigh what evil he is inflicting to the ethical world." One German scientist derisively declared that in reading Chladni's book it seems that Hladny himself had been struck with a rock.

The cosmic nature of meteorites was accepted 10 years later, when in 1803 a meteor shower fell in France and French academicians no longer could ignore an obvious fact. This curious case is a splendid example, unfortunately, of the often-encountered disbelief of theoretical facts as against observational facts.

Thus, the discussion of the origin of moldavites entered a new, third stage: either moldavites are cosmic bodies, or else they are terrestrial, but then what unique process led to their formation? Let us speak frankly, things went much easier in the debates for the advocates of the cosmic version: no one knew clearly what happens in outer space and they could fantasize about it as much as they please. In general, the meteoric origin was adopted: it was decided that moldavites are a variety of meteorites. No one was particularly upset by the fact that neither in composition nor in size do molda- /11
vites have anything in common with meteorites, but it is not difficult to draw a parallel in the nature of the sculpturing.

When the fact of the systematic arrival of meteorites became obvious to all, scientists proceeded to studying the surfaces of these bodies, usually covered with a fusion crust bearing the characteristic "breaker surf" rippling (regmaglypts) -- evidence of flight through the atmosphere. Something similar was also found for moldavites.

Much later, in the 1930's, the well-known enthusiastic in the study of moldavites, Czech engineer F. Hanus developed an

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[4] Meteorites (from the word "meteoros" -- hanging in air) are bodies of cosmic origin falling on the earth. Three classes of meteorites are distinguished: iron (nickelous iron with impurities), stony (olivine, pyroxenes, and other minerals), and iron-stony (pallasites -- after the meteorite Pallas Iron).

entire theory, according to which in the remote past an enormous meteorite travelled over the territory of Czechoslovakia, breaking up into fragments. It was what formed the beds of moldavites. Then also Hanus for the first time classified the sculpture of moldavites, singling out several elements in it (semispherical depressions, ellipsoidal depressions, deep folds -- "grooves", and wrinkles).

At the present time it is believed that the moldavite scattering ellipse is equal to tens of thousands of square kilometers, and that the total number of specimens preserved in museums and private collections is also in the several tens of thousands.

AT THE OTHER END OF THE WORLD /12

Charles Darwin Was the First. -- On How to Become a Doctor. -- Ten Million Finds. -- What Did the Ancient Birds Know About Australites?

In 1831-1836 when the debate about moldavites was still localized, the English naturalist Charles Darwin made his famous global voyage on the Beagle. He carefully described all that he saw on this long trip: animals and plants, minerals and rocks, the life and customs of the natives. Then this was published in several books and scientific articles.

When the Beagle weighed anchor along the coasts of Tasmania, Darwin, setting out in the regular expedition deep into the land, unexpectedly found hollow spheres of black glass on the ground, somewhat larger than a walnut. On carefully inspecting them, he took them to be volcanic bombs. However, there were no volcanoes nearby. This was confirmed by special geological routes followed. It remained to assume that the spheres had been carried here by nomadic natives. Darwin made an entry in his diary and then did not return to this question. The great scientist collected much valuable material, but the puzzling spheres were for him only a chance episode.

However, this find served as the starting-point for numerous discoveries in the Australian continent. Moving ahead, I state that these black glasses -- australites -- are related to moldavites, but exceed them by far in scale of distribution.

Besides Australians of European origin settling mainly the coastal regions, tribes of an indigenous population -- the aborigines -- lived in the continent. One would ask, what do the aborigines know about australites? They could not have failed to notice them if Darwin, on arriving there for the first time, found them at the very outset.

Naturally, in one of the subsequent scientific papers we read the following: "It was not Charles Darwin, but the aborigines who were the first theoreticians of australites. The inhabitants of the interior of the country (Dieri and neighboring tribes) knew /13 them under the name "ooga" and "muramura" along with the related legions... about"radiant eyes" and "emu eyes." Their origin was based on the views of Stone Age man giving them power... and used as tributes of mysticism and magic, usually for doctoring and rain-making."

The Australian ethnographer C. Mountford in a book recently translated in our country, Black People and Red Sands (Journeys in Wild Australia) /Korichnevyye Lyudi i Krasnyye Peski (Puteshestviye po Dikoy Avstralii)/ write that "australites are an inseparable possession of the "nungari" (medical persons), similar to quartz crystals with which the doctors of southern tribes treated patients. In the hands of the "nungari", these stones -- meteorites -- served various purposes. For example, on being introduced into the body, they restored lost powers, they protected property like a watchdog, they could detect where an enemy was located, they helped in curing fellow tribesman...." Further, the author told about one aborigine who received an australite from a medicine man to be inserted under his skin in the area of the solar plexus in order to himself become a doctor.

In other ethnographic studies we can also find curious information about australites used in medicine, burial and sorcery rites, and being carried as punishment and for good fortune owing to their apparently celestial origin.

But all of this became known only recently. The history of australites is very similar to history of moldavites. For long time after Darwin they were called obsidian bombs or obsidian buttons (Fig. 2), since the latter shape proved to be very typical. Then, when explorations into the geology of Australia began to be pursued quite intensively in order to establish the absence of volcanoes erupting such strange lava, the name "obsidianites" (that is, obsidianlike) appeared. Already by this time (the end of the 19th century) generally their cosmic origin began to be accepted, and after comparison with moldavites the term australites was finally attached to them.

The cosmic nature of australites proved not very difficult to demonstrate since they were continually being found on the surface of the barren Australian desert, along roadsides, in scanty soil /14
and young beds, being extracted from these areas during the recovery of gold and tin, over an extent of nearly 5,000 kilometers. Their properties vary geographically without any relationship to the local geology, which was quite variegated in this territory.

These scales of tektite formation are incompatible with any geological processes. Therefore, when in the mid-20th century an attempt was again made in Europe and America to revive the theory the terrestrial origin of tektites [5], it involved nearly no Australian researchers. These researchers included George Baker, who for 20 years annually published a paper on australites and who wrote the book Tektites /Tektity/, which became a manual for all interested in this problem.

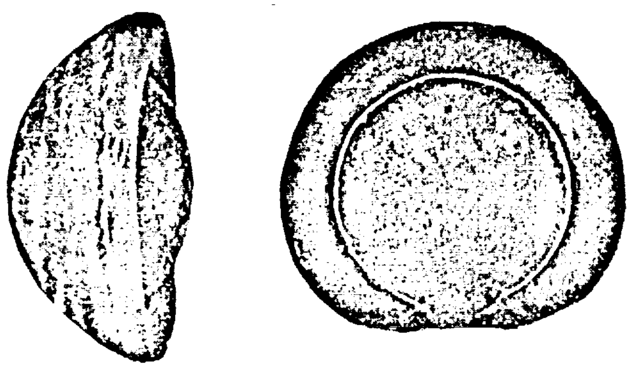

Fig. 2. Australite in the form of a button

The total number of australite finds is estimated at a maximum of 10,000. This is approximately one find per square kilometer (much less than in Czechoslovakia), although over some areas the finds were much denser. No australites were found beyond a line drawn between Brisbane -- Derby (in the northeast of the continent) (Fig. 3). The weights of the specimens vary between 0.15 and 280 g (averaging 0.934 g). Most of them are specimens of original shapes, and the smaller ones are fragments of these forms that are so typical of moldavites.

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[5] This can only be conventionally called theory, for it is negative in nature -- it does not advance any facts in its favor and emphasizes the weak points of cosmic hypotheses.

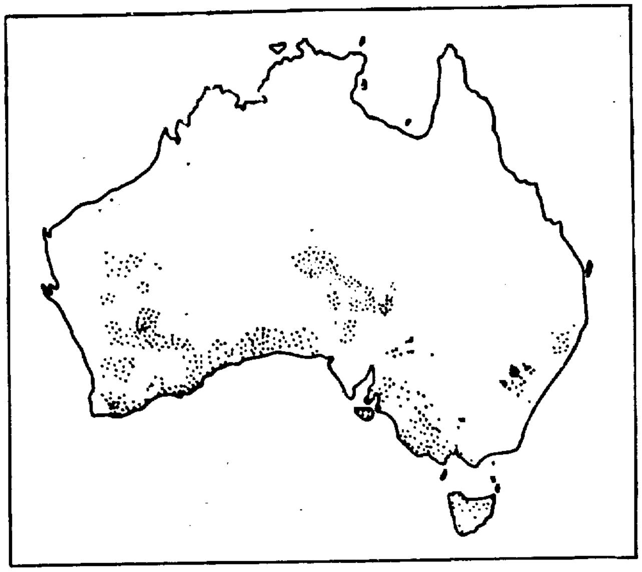

Fig. 3. Locations of australite discoveries /15

Continuing our comparison of australites with moldavites, we reason as follows: while moldavites are encountered less often on the earth surface and the state of preservation of their individual forms is worse, their age therefore must be greater. Australian scientists attempt to respond to this question with a simple and ingenious method. Biologists, exploring the stomachs of recently extinct giant heniornis birds, encountered among the gastroliths [6] all stones and minerals common to the given region, but no australites. Still, modern giant birds -- the emu, related to the heniornis, eagerly swallow australites together with other stones. On the basis of this the conclusion was made that during the existence of the heniornis australites had not yet fallen on the earth. This occurred later -- several thousands years ago.

Whether this conclusion was confirmed by reliable laboratory methods, we will relate below.

[6] Gastroliths (literally "stomach stones") are hard stones swallowed by birds for grinding of their food.

REGION THREE: SOUTH-EAST ASIA

"Black Diamonds"of Billiton Island. -- Philippine Excavations. -- Indochinite-Giant. -- At the Ruins of Forgotten Cities. -- Two Sensations of One Island

Three-fourthsof the world tin reserves are found in the cassiterite beds of the Malay tin-bearing province: Burma, Thailand, Malaya, the island of Bangka, and the island of Billiton. From dawn to dawn can be heard here the sounds of working dredges, which pass millions of tons of ancient pebble gravel through their maws -- the product of the disintegration of ore veins, extracting heavy cassiterites [7] from it.

A severe climate, arduous work. Among the prospectors and workers there are many Chinese, whose industry has been prized by British and Dutch colonizers. At the end of the 1870's though there was no trace of dredges as yet: all work -- extraction, beneficiation, and hauling -- was done manually in the mines.

Once Chinese workers found a piece of glistening mineral on the island of Billiton, which they gave the name of black diamond ("carbonado"). They could not conceal their find. The mine foreman packed it and sent it for expert examination to Batavia.

The expert was the Dutch scientist P. Van-Dyke, who investigated the specimen sent him, and was convinced at once that it was not diamond. Interest among industralists in the find waned, and the stone remained in the scientist's laboratory. Soon one of the scientific journals published a report on the "obsidians of Billiton," but the author added the qualification that the glass found could be of volcanic origin.

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7 Cassiterite ("casiteros", meaning tin in Greeks) is the principal tin-containing mineral (79 percent tin); owing to its mechanical strength it is well preserved in beds.

Fig. 4. Billitonites with "worm path" sculpture /17

Only after 18 years did another Dutch scientist, R. Farbeck, make a cautious assumption: aren't the "obsidians of Billiton" the lava of luna volcanoes? At that time this felt appeared so outrageous that it drew caustic gibes and was soon forgotten. Still, we have justified in regarding Farbeck as the founder of the lunar hypothesis -- one of the presently most trustworthy hypothesis.

In 1898 the same kinds of glasses were found on the island of Bunrugan (the archipelago of Natuna along the coasts of Borneo), and then on Borneo itself and other islands of Indonesia and, finally, on the Malayan Peninsula, receiving the general name of billitonites. Typical of the specimens are round shapes ("balls") and weakly pronounced sculpture, but sometimes with large "worm paths" (Fig. 4). The largest billitonite specimen weighs 750 g.

On reading about billitonites, ethnographers reported to the /18
geologists that the local Indonesian population knew of these stones for a very long time (for many generations) under several similar names --"moon stones," "lightning stones," and "thunder stones," and their celestial origin was apparently known to the indigenous people. Unfortunately, no documentary confirmation could be collected.

But more and more new reports about finds of black glasses continued to appear in the press. It was found that they are distributed over virtually all the Southeast Asia.

In 1926 archaeologists in the Philippine Islands, engaged in extensive excavations in the Province of Rizal found, the first such glass. Two years later the site of the excavations was visited by the scientists Baker and Overbeck. The latter, well familiar with billitonites, identified them, pointing out that the specimens found with great similarity bore several specific features, in particular, a fine sculpture figure ("chicken skin"). They were given the name of rizalites.

We are indebted to G. Baker for all of the principal information on the black stones of the Philippines. This talented investigator has expended great effort in analyzing their location in complex geological conditions, has carried out extensive archaeological and ethnographic research, and has reported at international congresses with fascinating papers. Unfortunately, most of his work remains unpublished and is stored in a library in the city of Manila.

The complexity of the geological occurrence of these glasses is the fact that besides the typical rizalites, Baker found billitonite-like specimens on the islands of the Central Philippines, and also glasses which are close to obsidians in their properties. All these, with the exception of the latter, began to be called philippinites. Later, geologists found rizalite-like glasses on other islands of Indonesia.

The conclusion suggests itself that at least two showers of celestial bodies, partially overlapping each other, occurred in this region.

The most interesting deposit of philippinites is found at Santa Mesa (the vicinity of Manila) -- in a gray bed of gravel 10-20 cm thick, lying on volcanic tuff and overlain with juvenile /19 river deposits. Of the other regions, mention must be made of the small island of Anda with the adjoining section of the coast of Luzon Island, where philippinites are found in the form of spheres, cylinders, and dumbbells with characteristic angular sculpture elements -- in the form of star-shaped scratches, seemingly gnawed by small rodents(in Baker's expression). The rock overburden here consists of yellow sandy strata with fine iron concretions and bone remains of mammals (elephants, wild pigs, and so on).

Fig. 5. Philippinite in the form of cracked head

Some of the later finds were made in Paracale (the Province of Norte Camarines on Luzon Island). Here are found specimens in the form of cylinders and spherical heads with deep networklike grooves, formed, as specialists assume, in cracking during the period of impact, compression, or tension, while the viscous glassy melt was cooling. One such specimen weighing 226 g (6.5 x 6.2 x 5.2 cm) is stored in a museum at the University of California (Fig. 5).

A total of more than 1000 specimens have been found in the Philippines. Of these, 90 percent were discovered in the Province of Rizal and the adjoining Balakan Province. The largest specimen weighs 1070 g.

It was established, as for other regions, that the local population knew of philippinites from remote antiquity. Burial sites of the Stone and Iron Ages have yielded arrow heads sharpened of these stones, along with amulets and talismans. At present they are known under several names: "taeng-kulog" (excrementa of thunder), "taeng-bituin" (excrementa of the stars), "batong-arao" (star stones), and "batong-anai" (termite stones). They have been used principally as implements of magic.

Simultaneously with the philippinites, discovery was made of /20
indochinites -- black glasses of Indo-China (Thailand, Cambodia, Laos, Vietnam) and South China, including the island of Hainan.

Nearly all field studies here were made by the famed French mineralogist Alfred Lacroix, climaxing his fruitful scientific life by the multi-volume work, Mineralogy of France and Its Former Overseas Territories.

Lacroix spent many years in equatorial forests from the Gulf of Bengal to the South China Sea and had travelled on barges up rivers where even during the day a mysterious twilight from trees linking their crowns with strong lianas rules. In the Museum of Natural History in Paris Lacroix gathered a unique collection of indochinites -- a set of wonderfully formed specimens: bulbs, drops, dumbbells, and so on (Figs. 7-13).

The crowning-point of his explorations was the discovery in the jungles of lower Laos of 2500 fragments of indochinite-giant, the largest of which weighed more than three kilograms, while the total mass amounted to 67.5 kg. From the location of this find, the specimen was given the name "muong-nong" and was classified as an independent type due to several distinctive structural properties. Further studies showed that "muong-nong" in its origin is still related to indochinites and, evidently, is a fortuitously preserved relict of an enormous parent body from which indochinites were formed in as yet unclear conditions and which fell in the form of a shower over Indo-China.

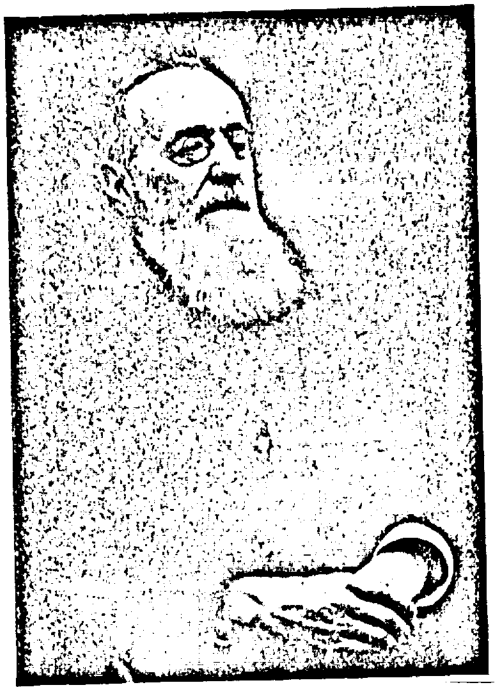
Considerable interesting data have been published in the French ethnographic literature stating what role indochinites played in the culture of the ancient and modern peoples populating these areas. In a description of the rites of the inhabitants of the island of Hainan flash names already familiar to us: "moon stones," "devil balls" and "excrementa of stars."

People collected and used these stones even during the Bronze Age and Early Buddhism, and from some reports even earlier.

The wild jungles preserve the secret of many ancient cities and temples, whose clearings were won by people from nature with such great labor, and nature so easily again returns them to the wild state.

Imagine to yourself a traveller exhausted by a long passage /21
through this green hell -- the jungle. And there, many hundreds of kilometers from inhabited areas, suddenly to his gaze appeared rubies surrounded by plant tendrils. An entire city -- a lovely creation of ancient architects -- was abandoned, forgotton, and was not spared by nature. The pyramid temple-tombs of the god Shiva point upward. Along the walls of the open galleries are hundreds of meters of bas-reliefs in mythological and historical subjects, and thousands of statues of seminaked asparas [8]. A tower with a four-facedhead is brushed by the roots of plants -- they envelop the head, penetrate into its mouth, nostrils, and even the furrows on the brow. The statue looks out in all points of the compass, and the gaze of its expressive eyes makes the hearts of even those for whom religion is only an object of art to beat faster.

/Footnote 8 on following page/



Alfred Lacroix

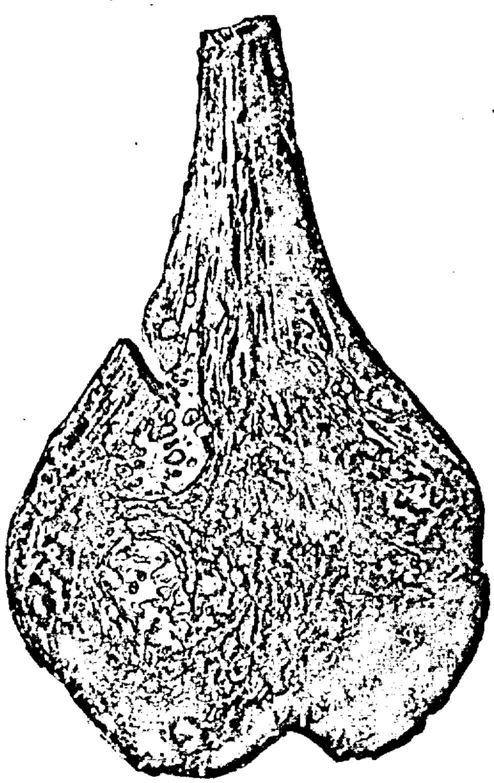


Fig. 6. Indochinite in the form of a bulb /22

All eight eyes of the statue were made of polished indochinites by talented sculptors.

The story of discoveries does not end with this.

8 Asparas are celestial beings created to serve the deceased, in ancient Indian mythology.

Let us move to Hong Kong of the 1930's. The Dutch geologists and paleontologist [9], R. Koenigswald, wandering the streets of the exotic city, entered a little Chinese shop. He was shown a small case containing piece of various animals, which he cursorily attempted to determine. And suddenly the scientist exclaimed from amazement: before him lay a giant human tooth, corresponding to an individual 2.5-4 meters in height.

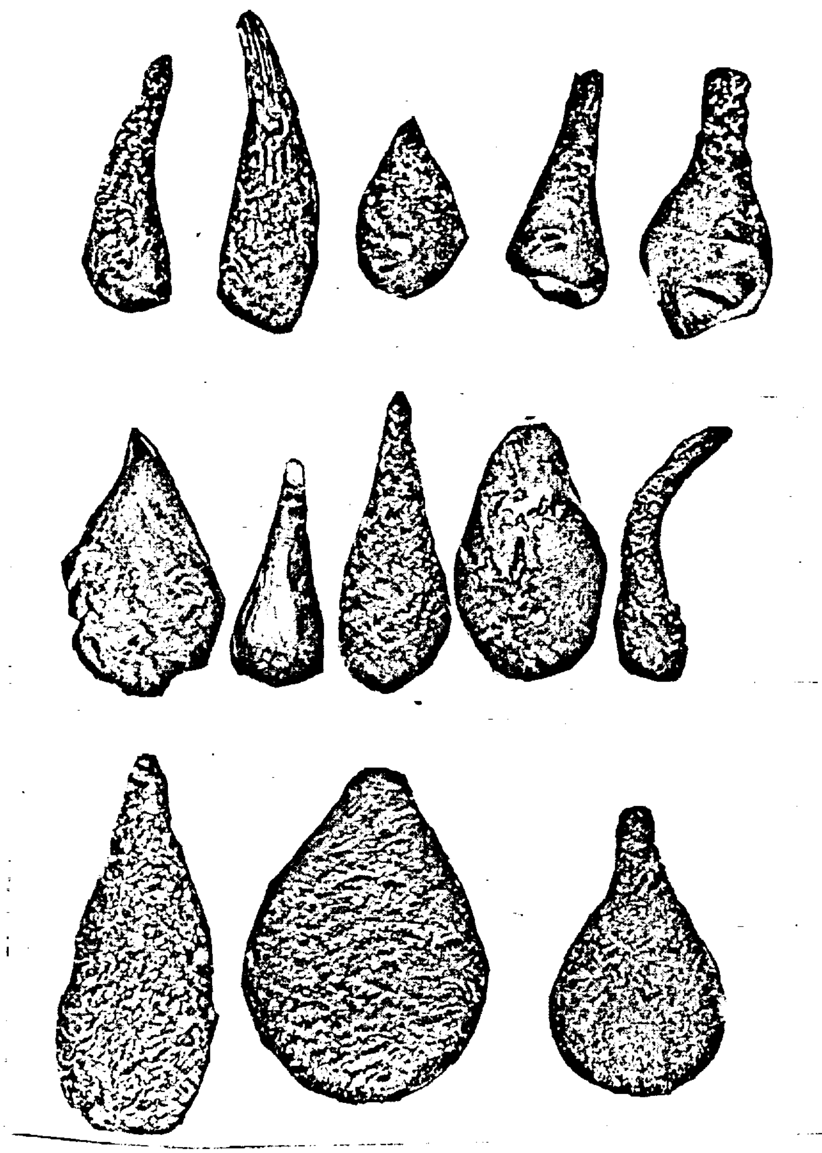


Fig. 7. Indochinites in the forms of drops and pears (from the collection of A. Lacroix) /23

[9] Paleontology is a science occupying the frontier between geology and biology and reconstructing the biological and geological history of the earth from excavated remains of organisms.

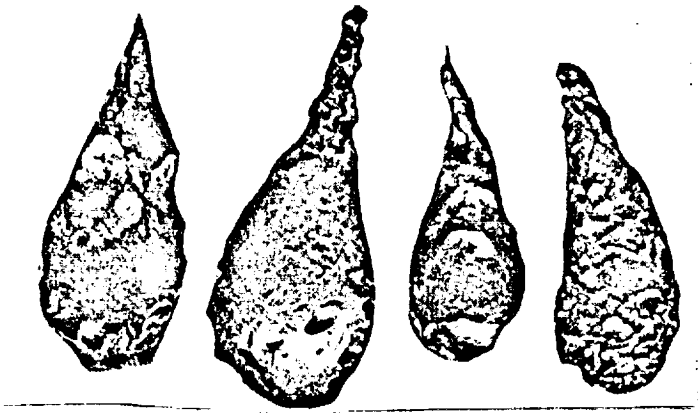


Fig. 8. Indochinites in the form of drops with sharp ends (from the collection of A. Lacroix) /24

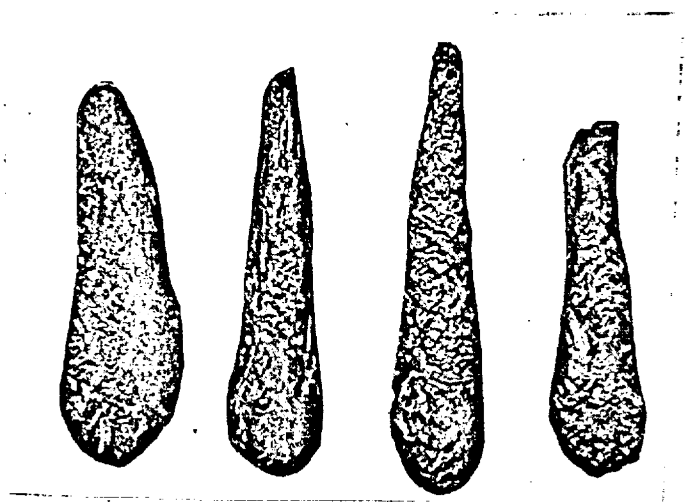


Fig. 9. Indochinites in the form of elongated drops (from the collection of A. Lacroix)

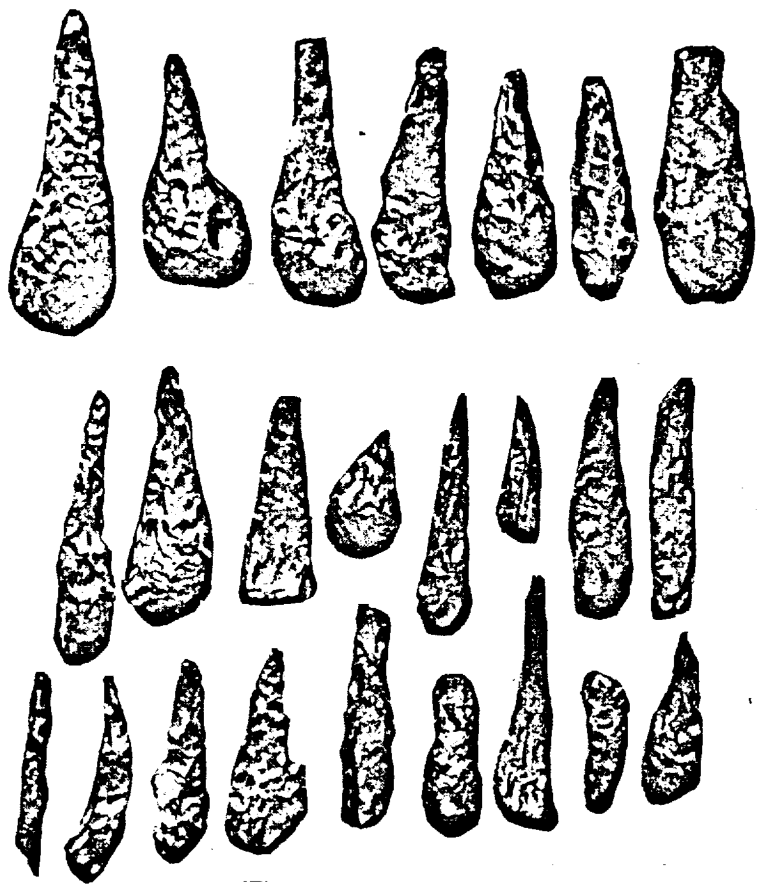


Fig. 10. Indochinites of coarse monopolar form (from the collection of A. Lacroix) /25

Thus was discovered gigantopithecus -- one of the closest and most amazing ancestors of man. The discovery led Koenigswald first to the Chinese province of Kwangsi, where giants lived in the caves of "yellow earth" 10 a hundred or five hundred thousand years ago, and then -- in 1941 -- to the island of Java.

Here an entire human skull with three teeth preserved was found during the excavations. The name "Meganthropus paleojavanicus" (giant-man from ancient Java) was given to this individual, 3.5 m in height. Along with his remains, the gravel yielded bones of elephants, hippopotami, pigs, and modern species of cattle, and also... black glasses of a completely new kind. Two amazing finds in one place! This does not happen often.

Javaites, or javanites, as they are called, are intermediate in several properties between billitonites and indochinites, and in other properties they are close to australites. Today 10,000 pieces of these are estimated to be in collections -- quite a

10 "Yellow earth" (loess) is a clayey rock of sedimentary origin, finely dispersed, and highly porous.

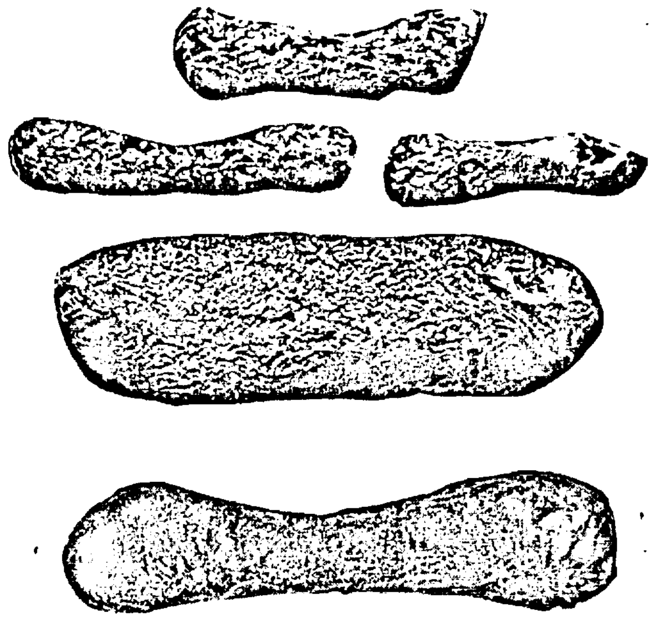


Fig. 11. Indochinites in the form of dumbbells (from the collection of A. Lacroix) /26

great deal for this island. The largest specimen weighs 400 g, and the smallest -- they are called "Javaite crumbs" (Fig. 14) -- can often be found in fields.

Owing to the double discovery, paleontologists, ethnologists, and archaeologists were able by joint efforts to quite precisely determine the time of fall of the javaites, which corresponds to the geological epoch of the Middle Pleistocene [11].

---

[11] The entire geological history of the earth is estimated to cover several billion years and is divided into four eras: Proterozoic, Paleozoic, Mesozoic, and Cenozoic. The two latter have three periods each: the Triassic, the Jurassic, the Cretaceous and the Paleogenic, the Neogenic, and the Quaternary Periods. The Pleistocene occupies the second half of the Quaternary Period, lasting for about a million years, and is in turn divided into three ages, the Early, the Middle, and the Recent.

Fig. 12. Indochinites in the form of cores (from the collection of A. Lacroix) /27

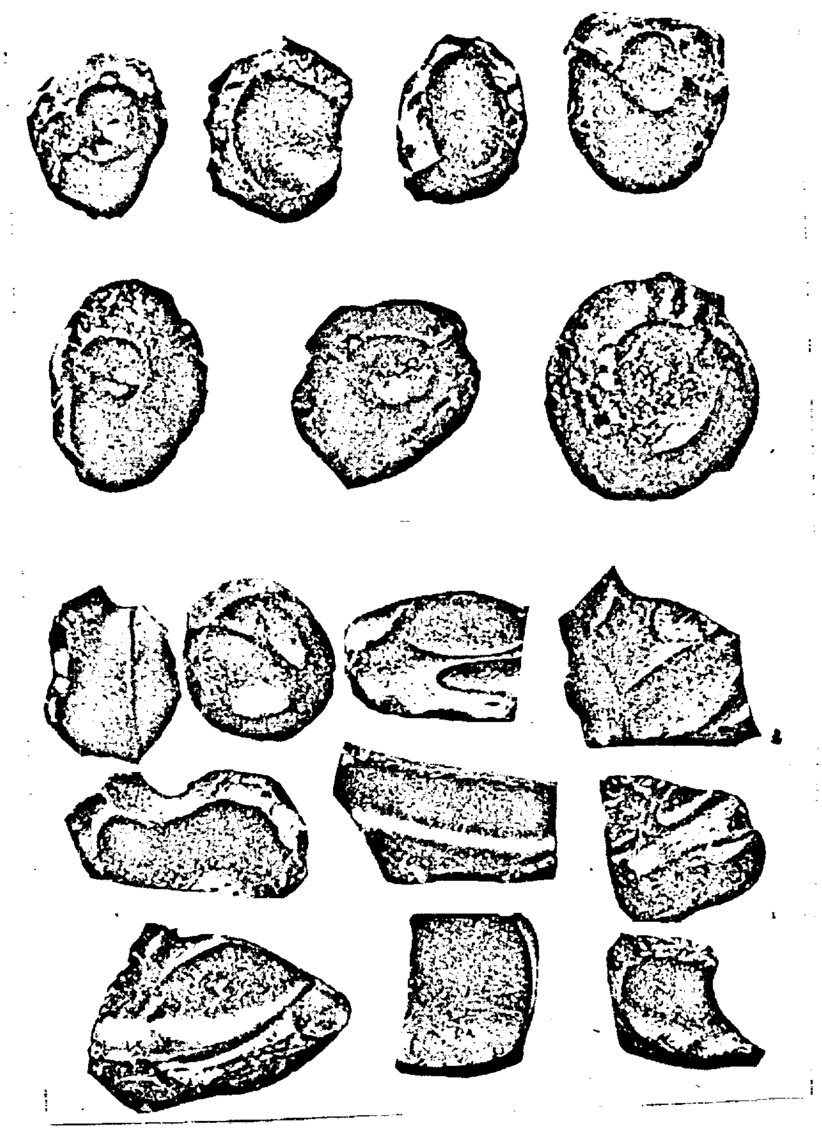


Fig. 13. Indochinites in the form of walnut shells (from the collection of A. Lacroix) /28

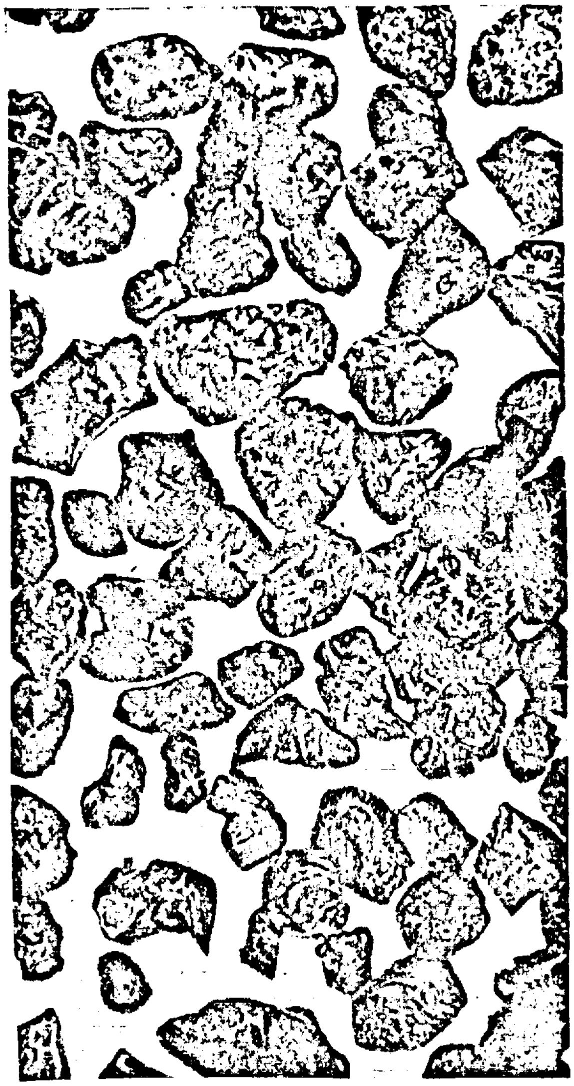


Fig. 14. "Javaite crumbs" /29

What conclusions can be drawn from the numerous data on South-east Asia? First of all, a geographical boundary (northern Australia, eastern Indonesia) lies between australites, on the one hand, and billitonites, philippinites, indochinites, and javaites, on the other. The fall of australites occurred then or somewhat later, when the isthmus between the two continents disappeared, which led, as we know, to the isolated development of Australian fauna. A true connection between billitonites, philippinites, indochinites, and javaites, thus far remains unclear, since we have to deal with individual fragments of land and we do not know which finds can be anticipated in the ocean. Here three variants are possible: /30

All the listed varieties are independent fields formed at different times, but in the same epoch. This "No" is very unpleasant to advocates of this version, since it is difficult to imagine that the adjoining regions one after the other were subject to tektite showers at specific intervals of time.

Southeast Asia, and perhaps even Australia, is a unified field, that is, the glass fell simultaneously over this large region. Then there remains obscure the quite abrupt territorial differences and displacements.

This variant is a compromise: there are several fields in Southeast Asia, but they do not all correspond to the above-presented varieties. It suffices to refer to the fact of the segregation by several researchers of indochinites into two independent groups -- northern and southern, and the provisional union of southern indochinites with billitonites.

Geography of Tektites. -- "Thunder Stones of the Ivory Coast. -- More on "Black Diamonds." -- Tektites Against Ivan the Terrible. -- Slag -- a Disrupter of Boundaries. -- On an Old Camel Track. -- Glass Named After Darwin. -- Outer Space Bombards the Earth. -- If Lightning Strikes a Rock. -- Tektites and the Atomic Bomb

Thus far we have steered clear of the word tektites, though it is not difficult to guess that moldavites, australites, billitonites, philippinites, indochinites, and javaites are tektites. This term was first used in 1900 by the famed Australian naturalist Franz Suess, who is justly regarded as the father of the science of tektites. He made a scientific identification of the three then-known varieties (moldavites, australites, and billitonites) and detailed and substantiated their cosmic origin, predicting the probability of further discoveries. The word tektites (from the Greek "tektos" -- melted) rapidly entered scientific usage and came to be used along with regional names.

Many have raised and continued to raise the question: Is there not a definite relationship in the distribution of tektites in the world? As facts accumulated, specialists entered this question in different ways. At first they wished to represent the distribution of tektites in the form of a zone encircling the earth from the southeast to the northwest.

This opinion was maintained for 7 years and was abandoned after a report by A. Lacroix already familiar to us on the discovery of tektites in French West Africa (Ivory Coast). On analogy with Australia, it was believed that this discovery would serve as the beginning of numerous finds in the African continent, but no more reports followed. Today we already know the reason for this: the African tektites prove to be so old and, naturally, they are well hidden by younger geological deposits. They also played some rule in the rituals of the local population -- the Baule: Nyamye [12] will give people longevity if they live righteously but in his wrath hurls sharp-edged stones on the earth during times

[12] Supreme god.

of thunder. These polished stone implements were often found by the Baule on the ground in working their fields. In order to come into contact with the forces they embody, they are suspended as amulets or are boiled in water and then the resulting "strong broth" is used in washing /Khimmel'kheber/. /32

The African finds alter the geography of tektites and made it possible for some to see a definite "augury" in the equatorial location of the tektite fields. (For some reason no one was disturbed by the fact that the principal fields -- the Czechoslovakian and the Australian -- are not at all located on the equator.) On this score, the so-called "soil hypothesis" rose, attempting to revise the theory of the terrestrial origin of tektites. Its author reasoned approximately as follows: We know that the formation of lateritic aluminous ores are related to soil processes in tropical climatic condition; since tektites are enriched not with aluminum, but silicon, it can be assumed that they were formed by the action of soil (humic) acids on solid silicic acid separating during the decomposition of tropical plants. Even in a general examination this hypothesis does not withstand any chemical criticism and, of course, was unable to win advocates for itself.

Nonetheless, the "equatorial" tektite finds continued. A major event was the report of the discovery in the acquisitions of the Mineralogical Museum in the city of Bogota of tektites from Colombia, and then on the other side of the equator -- in Peru. This novelty was greeted with such enthusiasm that at first no attention was drawn to certain inconsistencies between these specimens found and the classical tektites, which by that time (1925-1936) had been studied quite closely. By established convention, they were christened americanites, but ... this name rapidly grew out-of-date. The skeptics rejoiced. The point was that the americanites prove to be no tektites at all, that the actual tektites were discovered later, in 1936, in the United States. But more about this later on.

The controversies occurring in Europe had up to a certain time not particularly stirred Americans familiar with the problem only from articles made of australites imported by enterprising merchants and sold to American jewelers at 50 cents a piece. But /33
now in 1936 the geologist Ramsay and his colleagues discovered unknown black pebbles in the state of Texas while prospecting for

oil. The curious case repeated itself: they were again taken for black diamonds. True, the error was rapidly corrected, and under the provisional name "volcanic glass" the pebbles were sent to a museum for examination. The year was 1936, and not 1836, and Texas, not Indonesia, where nearly every island is a volcano. By what means could they be volcanic rock in Texas, in typical sedimentary deposits of the Eocene [13]? This fact spurred the American scientists to attend more seriously to solving the puzzle. And knowing the world literature quite well, it was not difficult to find the proper answer.

And thus, the first tektites in the United States! Just from April 1936 to December 1938 geologists collected 482 specimens in a small area with coordinates 30°33' - 30°41' S. A. at. and 96°03' - 96°09' N. Long. The specimens were called bediasites from the name of a local Indian clan. Many scientists decided to seriously study the problem of tektites. One of them was Virgil Barnes, who has now become a most eminent specialist and the author of an interesting hypothesis. Later, the geologists were joined by astronomers, who propose their own, no less original ideas.

In spite of the great activity of the prospectors, tektites for long time could not be found outside the state of Texas. Scientific publicity was called on for assistance. Popular journals published a series of articles; specialists gave lectures and read papers; field collectors of the geological service underwent training. Many enthusiasts from the local population -- farmers, teachers, farm workers, and Boy Scouts -- participated in the searches.

Finally, in 1959 Barnes reported on the discovery of tektites in the state of Georgia, which is separated from Texas by three other states. Over a distance of a hundred kilometers finds were uncovered one after the other (Fig. 15). But the problem of tektites was not clarified, but clouded. As it turned out, the tektites of Georgia (they were suggested to be referred to as empirites from the name of Empire County) were not at all similar to bediasites, but more closely resemble moldavites. A bold conclusion suggested itself: Are not Georgia and Czechoslovakia the antipodes of one enormous field? This proposal was advanced /34
by a specialist on glass technology, Alvin Cohen, however it

[13] Cf. footnote on text page 27 /translation page 27/. The Eocene is the Middle Paleogene.

remained up in the air, since to scoff at the brilliant idea or to accept it right away was risky: one could put his foot in his mouth.

Fig. 15. Tektite was found here along a road side (state of Georgia)

A new find was celebrated in the same year of 1959, and now in another region of the United States, in Massachusetts. A single solitary tektite lay at the bottom of a long rain gully on the nearly sheer coast of the Atlantic Ocean. The gully began 75 m from the location of the find and exposed geological strata of the Early Pleistocene, Myocene, and Late Cretaceous [14]. The Myocene is the Early Neogene. Therefore, it was not clear from whence the tektite had been carried. In any case, its age was quite great even if not the longest for nontektites. The form of the specimen was very strange -- it resembled a quarter of a gear wheel (Fig. 16). The initial disk evidently weighed about 100 g. Sculpture furrows were very similar to moldavite grooves. The color was black, but it transmitted green well. In composition it partially resembled moldavite, and partially bediasite.

Thus, the American explorations even though proving to be fruitful, nonetheless led to a confusion of views relative to the boundaries of the tektite strewnfields. The only thing that can be said is that evidently the territory of the United States /35
was the arena for several falls of tektite showers. How many they were, the future will tell.

Searches are continuing in the United States. How the program is being correlated with the concepts of the origin of tektites will be told in the Chapter "Meteorites? Comets? Moon?"

[14] Cf. remark on text page 27 [translation page 21].

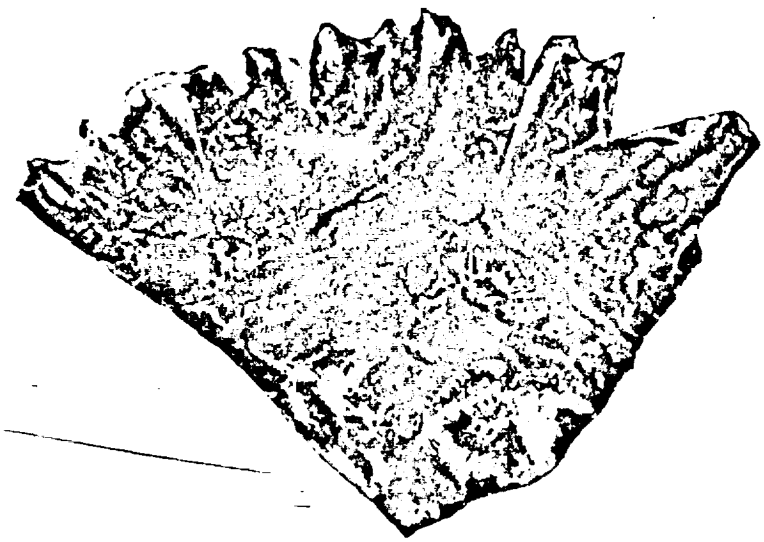


Fig. 16. Tektite of the state of Massachusetts

The description of the various territorial groups of tektites can be concluded with the story of several unverified finds of these bodies.

Once workers in Ceylonese semiprecious stone mines found pieces of a lovely dark-green glass in a pebble bed. In contrast to the first discovery of the billitonites, these workers proved to be fairly good experts on decorative stones and immediately determined that this was not mineral. However, they further followed another, perhaps, false approach, on deciding that they were dealing with remelted bottle glass and threw it into the barren rock dumps. Several years later one of the specialists working here, on reading about tektites, remembered this case, but the green glasses were no longer to be found in the mines. Of course, it would be tempting to establish that this had been tektite. All the more so because an enormous tektite region lies alongside Ceylon.

Quite recently I received two letters from India with a report of the discovery there of unusual glasses. But this report also required verification. /36

I worked for several years as part of a geological expedition in Mongolia; there I met with the famous Mongolian scientist B. Renchin -- a philologist, archaeologist, polylinguist, and writer. He had been interested in our problem and he recounted the role of tektites in the ancient culture of his people. Mongolian shamans used tektites as a magic implement for rain-making, while the pagan Tatars, besieged in Kazan by the forces of Ivan the Terrible, issued order to them as their last means of "defense": they solemnly carried the stones to their entrenched lines and began to pray that the siege would be lifted. But the tektites did not help them: several days later the Russians entered the city. It is difficult to say whether these glasses (if they actually were tektites) belong to an independent territorial variety or whether they were brought to the north as a result of religious-cultural ties with southern peoples.

We recall the debate in the American press on the nature of the puzzling pebble of dark glass, whose external structure makes it similar to tektite, and its internal structure -- to obsidian. This pebble was found in the state of Oklahama and after long thought was classified with the pseudotektites.

Thus, imperceptibly the problem of tektites merged into another and perhaps no less important problem, but one that is no less difficult, the problem of pseudotektites and silica-glasses. If it were possible, we would try to keep silent about it, but then our account would be incomplete.

Pseudotektites include several groups of glassy bodies, directly or indirectly (sometimes due to lack of understanding) associated with tektites. These first of all include the americanites already familiar to us, the variegated-colored obsidianlike glasses from the Philippines and Patagonia, the Swedish green glass -- scanite, about whose cosmic origin a controversy lasted for more than 30 years, the unusual meteorite Igast, falling in 1855 in Estonia and several times attracting attention as a possible tektite, and so on.

The glassy, slaglike bodies found in the most puzzling circumstances occupy a special group; thus far science has come forth with absolutely no conclusion as to their nature. In due course, together with our Mongolian colleague we described one of these /37
slags under the name "Kerulenskiy pseudometeorite." On 21 March 1950, about one o'clock in the morning local time Mongolian frontier guards observed the flight from the direction of the Great Hingan of some body, which crossed the frontier and fell on a dry river valley. A tabular lump of gray-green slag with white impregnations of fused quartz was found at the impact site, breaking apart into 355 fragments with a total weight of about 28 kg. Now the Kerulenskiy pseudometeorite (which the Mongolian press incorrectly called a tektite) is stored in a museum in the city of Ulan-Bator (Fig. 17). The same phenomenon was observed recently in Poland and the same type of slag was found. Turkmen geologists discovered in 1956, in the southern part of the lowland Kara-Kumy, without any trace of volcanic or industrial activity in this

region, beds of an unknown slaglike material at the bottom of a takyr [15]. The list of similar occurrences could be extended.

Silica-glasses as such refer to pure glasses of silicate composition. As we know, silicon is one of the most widespread chemical elements in the earth's crust. In terms of the relative content of silicon dioxide (silica), igneous, that is, magmatic, rocks form a continuous series from basic (50 percent) to acidic (more than 65 percent) varieties. Of the sedimentary rocks, the most "acidic" are sand and sandstone, consisting nearly entirely of grains of pure crystalline silica -- the mineral quartz. Silica-glasses approximate glass in composition (about 90 percent silica, that is, 20 percent more than in tektites), but differ in their amorphous (glassy) structure. We will consider two kinds of silica-glasses, bearing the closest relationship to tektites -- Lybian desert glass (lybite) and Darwin glass (tasmanite).

Let us transport ourselves mentally to some period of time in Egypt.

... The Lybian Desert. Heavy burning air shimmers over scorching sand. Camels trod heavily, at times nearly hidden behind tall dunes. The white figures of bedouins are motionless, wrapped up in their burnooses.

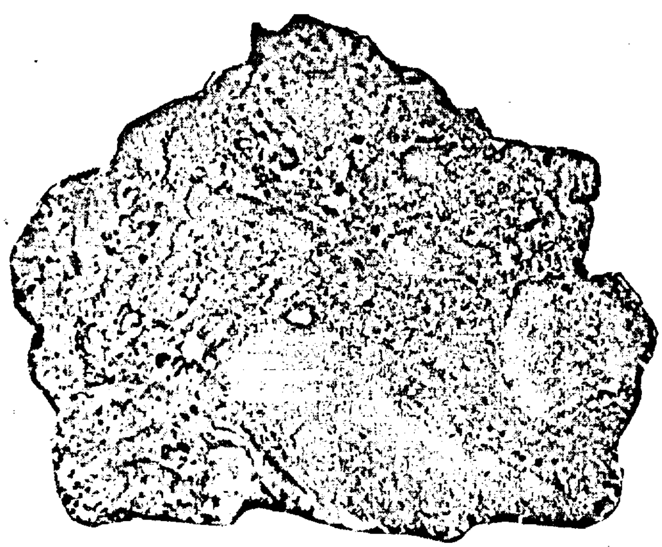


Fig. 17. The Kerulenskiy pseudometeorite or pseudo-tektite /38

The caravan has been travelling the route between the Kufra Oasis and Abu-Migtar for many days now. The old and, seemingly, reliable camel path has disappeared. All the provisions carried have been used up....

15 A takyr is one of the elements of the desert landscape, consisting of depressed sections of the terrain filled with clayey sediments that turn boggy during the rainy season.

The caravan perishes. This happened in 1810.

Six years later in search of the lost path a special expedition set out from Cyrenaica to Egypt. The blue sky blanched from the heat and the faded yellow-gray sands are all that the eye can see. On the second or third day of the journey the travellers set up a major halt. An Englishman Bertard, accompanying the caravan, looked around with curiosity, stretching his legs that had turned numb from his sitting for a long time in an inconvenient posture. Sand, sea of sand! And, as in the actual sea leaving dead fish, fins, and seawweeds on the shore, the wind of the desert gathered a variety of various refuse between the dunes: bones of animals, clay crocks, and small transparent bits of glass. "What could this be?" The Englishman asked himself. "Amazingly pure,
transparent, shapeless glass. Glaze? Not likely. Pieces of a /39
glass dish? But from whence would the nomads get such a dish?" He decided not to question his fellow travellers, in fact it would be hard for him to do so since he knew nearly no Arabic. Placing several glass fragments in his pocket, he decided to continue to the end of the journey.

In December 1932 the same glasses (Fig. 18) were discovered by P. Clayton, and in the same area. He reported about this to the famous mineralogist Leonard Spencer, the head of the Mineralogical Department of the British Museum and the one, who joining up several years later with a passing motor vehicle expedition, decided to personally familiarize himself with the area of the finds.

The vehicles travelled long without discovering a clear advantage over the "ships of the desert" -- camels. Now and then the water in the radiators boiled over. It was terrible to touch the scorching metal.

Finally, Spencer was at his destination. Shielding himself from the burning rays of the sun with a large linen umbrella, he carefully attempted to study the locale as far as the patience of his fellow travellers would allow. And this is what he found.

Lybian desert glass is encountered in an area with the coordinates $25^{\circ}02'$ -- $26^{\circ}13'$ N. Lat. and $25^{\circ}24'$ -- $25^{\circ}55'$ E. Long. in corridors 2-3 miles wide, between dunes 300 feet in height and 1-2 miles wide, extending from north to south for more than 200 miles (Fig. 19). Glasses together with fragments of man-made utensils are concentrated mainly at the surface in the form of pieces of irregular shape weighing from several grams to 7.25 kg. Here and there they form aggregations -- "patches". In one such patch 2 x 2 m in extent the scientist found 111 fragments. A monolithic Nubian sandstone -- the native rock of the desert -- recovered for verification, 2 x 2.5 m in size, contained only individual flakes of glass at a depth not exceeding 1.18 m.

Naturalists became interested in the uncommon discovery and in subsequent years several of them visited the Lybian Desert, detecting the same glasses 200 km from the region described where they evidently had been carried by nomadic Arabs or prehistoric man.

The second stage of investigations commenced. It was necessary to find out from whence the glasses had reached the Lybian Desert and to suggest more or less plausible hypotheses. The main role in these investigations belonged to Spencer, who unswervingly linked his scientific career with the problems of tektites and silica-glasses. We will tell about Spencer's hypothesis elsewhere in this book, but here we only note that present-day views attribute the formation of libyite to the explosion of some cosmic body, with the fusion of the quartz sandstone of the desert.

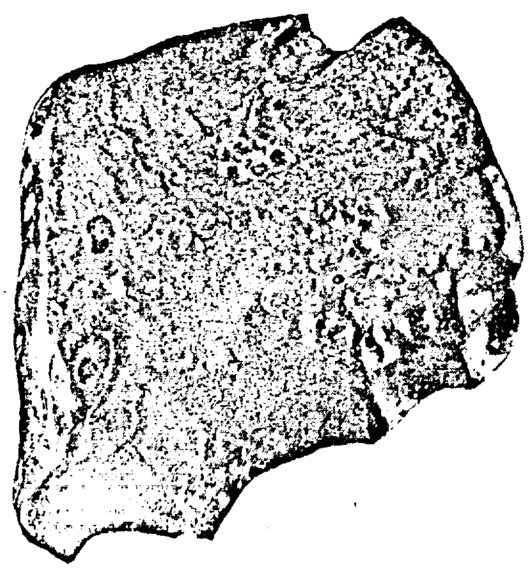


Fig. 18. Lybian desert glass /40

Tektitelike bodies with a very high silica content were detected in Tasmania, besides australites. F. Suess was the first to report about this, in 1914.

Tasmanites are found in the area of Mount Darwin in Queenstown. Therefore they are also called Darwin's glass and queenstonites. The country rock is quartzite gravel under a layer of peat of postglacial age, with a depth of occurrence of 9-18 inches. One-fourth to one-half ounces of glass are found per square foot of the gravel bed. Typically, tasmanites are absent on Mount Darwin itself (1300 feet elevation). This is due to the work of the glacier sweeping the glass downward and concentrating it in valleys. The color of tasmanites varies from nearly black or black-green to dark-smoky with individual white patches owing to a large number of bubbles. Their shapes are uncharacteristic.

Leonard Spencer /41

Views as to the nature of tasmanites have changed very often. They have been grouped with tektites, removed from this category, again placed in this group, and now they are ascribed, as silica-glasses, the same origin as libyite.

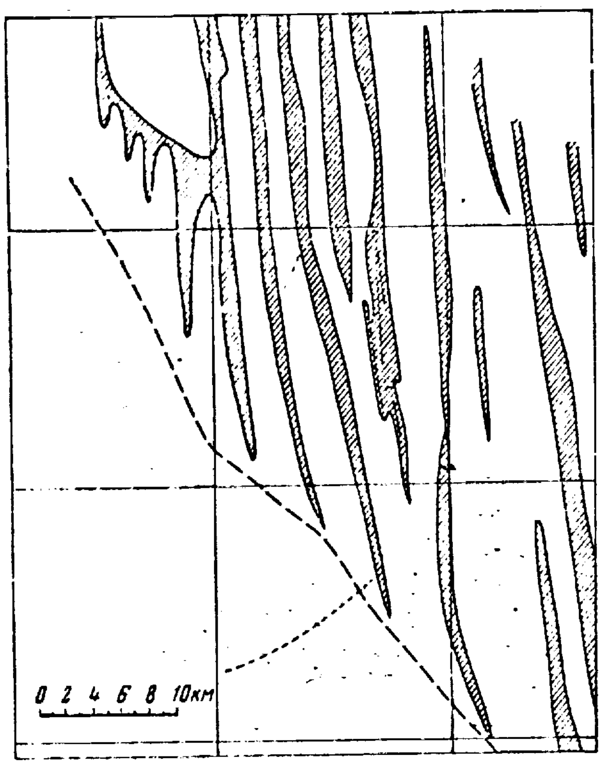
In addition to silica-glasses of puzzling nature, science knows of three kinds of authentic silica-glasses: one is of cosmic origin, the second -- of terrestrial, and the third -- of artificial origin. These glasses bear only indirect significance in the problem of tektites: first of all, by knowing the conditions of their formation one can extrapolate to the unknown conditions of tektite formation; secondly, several specific hypotheses of the origin of tektites are associated with them, and even further silca-glasses must engage our attention as objects of an interesting comparative investigation.

A general term is applicable to all of these materials -- impactites (from the English word "impact"), since they owe their formation to an impact (explosion), accompanied by the melting of silicate rock.

Meteoritic silica-glasses (with respect to which the term "impactites" was applied for the first time) were formed as the result of meteorites falling on the earth. As we know, outer space systematically bombards the surface of our planet with meteorites, sometimes more frequently, and sometimes less frequently.

With a small initial mass and on being decelerated when passing through the atmosphere, a meteorite, like an artillery shell losing its velocity, simply falls on the earth, making a shallow /43

Fig. 19. Corridors between dunes in the desert where Lybian desert glass was found /42



indentation in the soft ground or glancing by ricochet from the hard ground. A case is known when travelling at speeds up to 100 m/sec a meteorite penetrated the roof of a garage by its weight and fell on the soft seat of an automobile. If it had been immediately picked up by hand, it would have been mildly kilned, since it had been heated up during its flight through the atmosphere.

An altogether different effect results when enormous meteorites weighing hundreds of thousands of tons and retaining some of their outer-space velocities (up to 5 km/sec) fall. On striking the earth, they explode, forming craters.

Several millennia ago a meteorite of this kind fell on the island of Saarema in Estonia. It broke up into fragments in the air, forming a number of craters. The largest of these, 110 m in diameter, is a regular circle in the plan view. Around the crater rises a ridge 6-7 m high, consisting of upthrust dolomite strata. With time a picturesque lake formed here, surrounded by luxuriant groves of trees and bushes. Alongside the lake is the school of the settlement of Kaaliyarv, which in the summer serves as a resort for numerous tourists visiting this "miracle" of nature.

Giant craters include the famous Arizona Crater in the United States, 1207 m in diameter, formed as it is assumed, in the descent of a meteorite weighing 500,000 tons, from which only 10 tons were collected, in the form of small pieces. The age of the crater is 50,000 years (Fig. 20).

When a large meteorite falls on rocky ground (silicate rocks), impactite is formed at the site of the explosion -- silica-glass saturated with meteoritic material in the form of minute droplets of nickelous iron. These impactites were first described in detail by the investigator of Lybian desert glass, Spencer, in the meteoritic craters of Wabar (Arabia) (Fig. 21) and Henbury (Australia).

Both in the crater itself as well as the surrounding territory, an inquisitive researcher can always find microscopic droplets of iron or glass, whose shape in general resembles the shape of tektites (spheres, pears, dumbbells, and so on) (Fig. 22). Essentially this is actually cosmic or meteoritic dust -- drops swept along with the streaking meteorites and found on the surface of the entire globe. In industrial regions it is easily confused with industrial dust containing products of welding, from which it is differentiated by the presence of the typical element of meteorites -- nickel.

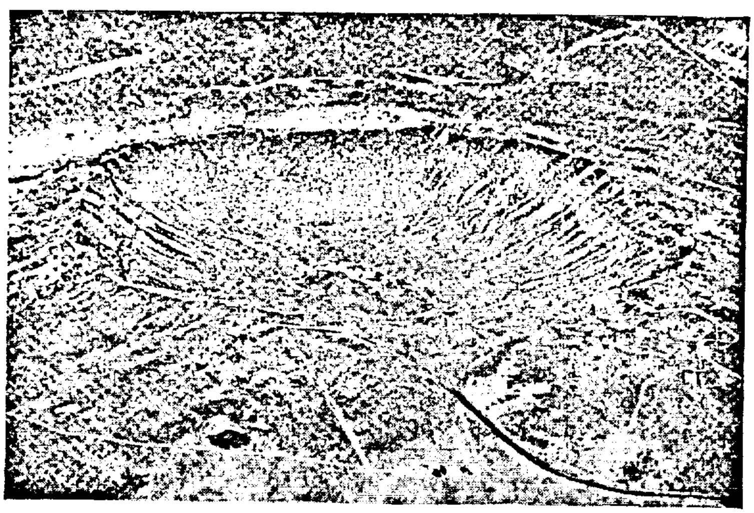


Fig. 20. Arizona meteorite crater. view from an aircraft /44

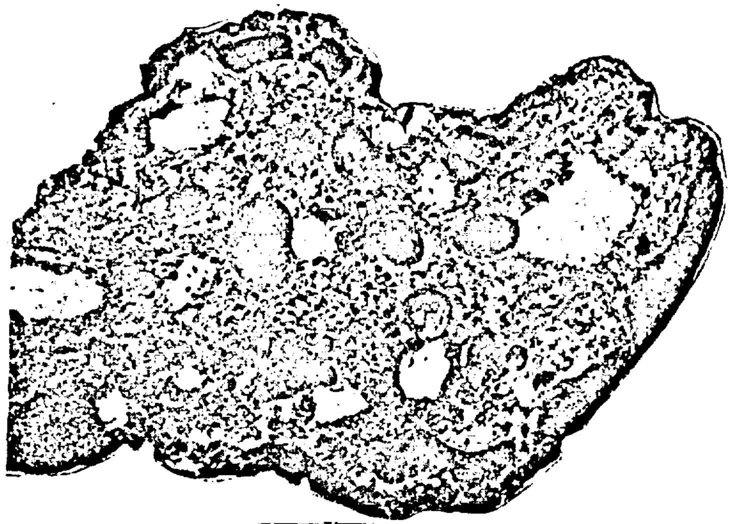


Fig. 21. Silica-glass from the meteoritic crater Wabar (Arabia)

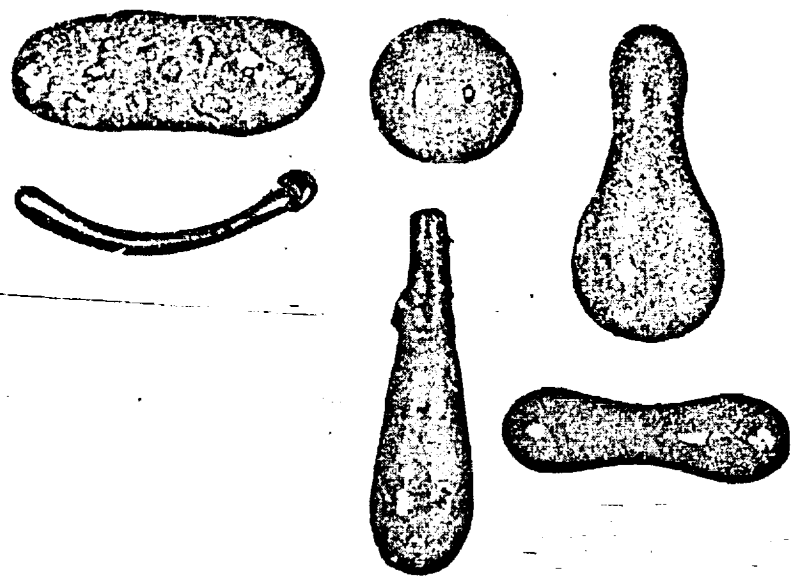


Fig. 22. Glass drops from the area of the meteoritic crater Al Hadidakh in Arabia /45

Even more typical of meteoritic silica-glasses is the presence of pure amorphous silica -- the mineral lechatelierite, very rarely found in nature, and present also in tektites. In other properties, the silica-glasses and tektites are little similar to each other, and moreover the composition of the former depends very heavily on the composition of the rock where the meteorite struck.

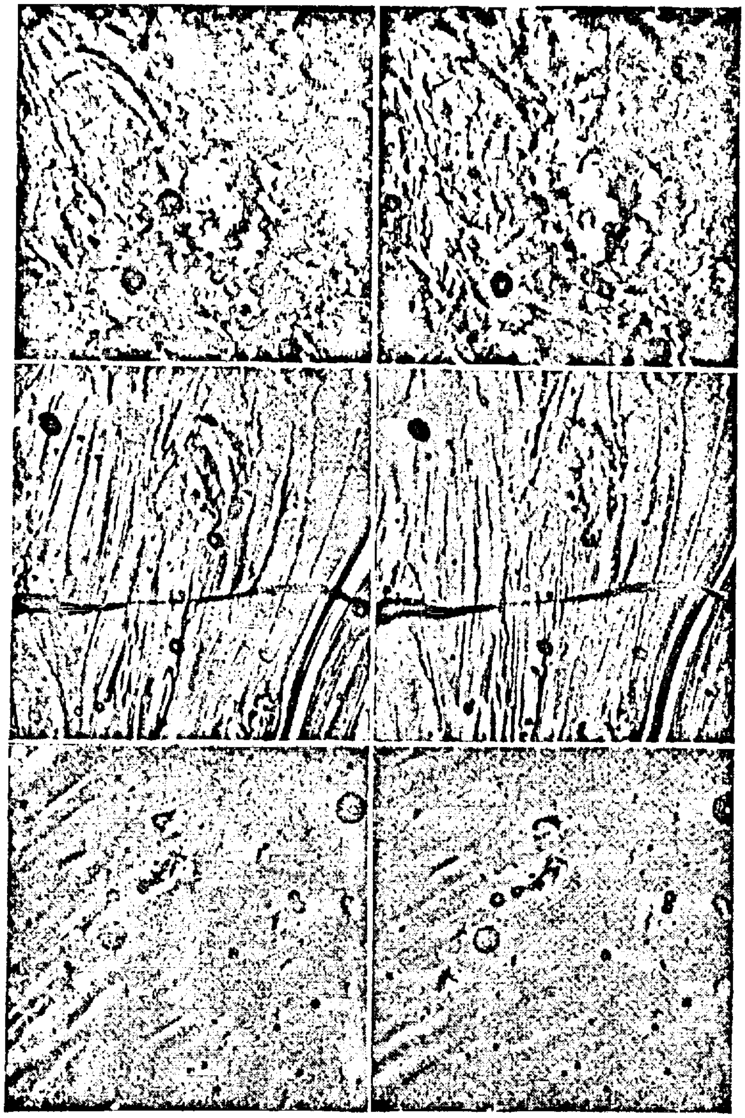
Nearly all known meteoritic craters and impactites were formed in the fall of iron meteorites. This is accounted for by the fact that a body in flight at high velocities encounters strong air drag (up to 100 kg/cm^2) and often as the results breaks down into smaller particles, forming a scattering ellipse of various sizes on the earth. An example is the Sikhote-Alin meteoritic shower on 12 February 1947, which formed 24 craters. Stony meteorites, /46 being the weaker, must disintegrate more easily and therefore their crater-forming properties are less strongly evidenced.

Among the inauthentic meteoritic craters containing silica-glasses are included Ries-Kessel in the Federal Republic of Germany and Bosumtwi in Ghana; the so-called impact-meteorite theory of the origin of tektites was developed on the basis of a material, in particular; this theory will be dealt with below. In a report on "tektites" of Ghana recently published in Nedelya /the weekly supplement to Pravda/, silica-glass found there is improperly referred to by this name.

The only authentic silica-glasses of terrestrial origin are the fulgurites (from the Latin "fulgur" -- lightning). As we know, thunderstorm lightning, on striking elevated objects, can split and scorch a tree, cause fire in the home, and kill a man. Fulgurites are formed if lightning strikes silicate rock, for example, in sand or sandstone. They are in the form of branched glassy tubing extending from the site of impact deep into the rock, and are often encountered on mountain peaks.

Fulgurite glass also contains lechatelierite, thus confirming that in energy of formation tektites and all the silica-glasses described have something in common.

This feature then served at one time as the basis for the so-called fulgurite hypothesis, according to which lightning melts silica dust in air, forming tektites. Later this process was transferred to the ground -- after the report of the find in Canada not of sandy, but of clayey fulgurite, apparently similar to tektite. However, this report was not confirmed and the hypothesis again died away. One must be candid and admit that the theories never were valued very highly and at the present time are more properly curious, rather than scientific-historic, facts.



A

B

C

Fig. 23. Structure of atomic impactite (A), moldavite (B), and bediasite (C) under the microscope. Inclusions of gases and lechatelierite can be seen. /47

In 1945 atomic explosions over the Japanese cites of Hiroshima and Nagasaki caused not only massive death to the population, numerous fires, but /48
also the destruction of buildings and the fusion of silicate rock. The products of the fusion -- atomic impactites -- were subsequently studied by Japanese scientists.

Another explosion, on Bikini Atoll, did not lead to the formation of impactites, since the only rock there was limestone (calcium carbonate), which undergoes vulcanization and vaporization.

Atomic impactites were studied closely in the United States after numerous underground nuclear explosions. Silica-glasses produced are more similar to tektites than other silica-glasses, in form, color, and structure, but nonetheless differ from them (Fig. 23). On the other hand, scientists observed a relationship between atomic and meteoritic impactites, finding a new mineral in both -- coesite -- crystalline silica with more dense atomic packing, which is evidently due to the greater pressuredduring the explosion. This mineral has been found in tektites only quite recently.

Summing up the foregoing, it must be noted that the cosmic nature of actual tektites has already been proven, but where the actual boundary between the tektites and terrestrial formations lies is as yet unclear. The study of pseudotektites and silica-glasses of known and unknown origin can serve as the key to the solution to this problem. But thus far no one has been able to select this key.

We recall the story of a physician specializing in poliomyelitis. As soon as a method of curing this disease was found and the epidemic went on a decline, by chance a new disease was discovered, accompanying poliomyelitis and very similar to it, but not amenable to treatment. Earlier it was simply allowed to pass and assumed to be poliomyelitis... This was approximately the relationship between tektites and silica-glasses.

Oblivion and Fashion. -- Tektites in the Hands of Fantasizers. -- Gift to a Queen. -- Four Experiments

Years passed, and the subjects for stormy debates about tektites were mainly exhausted. No one had at any time seen their fall. The historians could give nothing concrete by way of assistance. Science then approached the problem of their cosmic origin purely empirically -- based on logical arguments and not without the participation of bold intuition. Scientists were unable to set up an experiment that could at once remove all doubts. Scientific skeptics again raise their heads. And, finally, it was decided to put the problem aside until a better time. Moreover, World War Two broke out and for many specialists tektites were not the primary concern.

Of course, tektites were not forgotten about to the extent that help from archaeologists and archivists had to be called on. Many of them, whose names are given above, continued to selflessly labor, but the articles appeared less and less often; scientific centers did not eagerly release funds for studies; organizing committees of symposiums refused to include this subject in their agendas; and museum personnel hid indochinites and moldavites in the most remote corners of their displays.

In other words, tektites ceased to be the fashion (in the best sense of the word), the fashion which mobilized specialists of various disciplines introducing their ideas and methods and often promoting the solution of scientific problems.

On leafing through the journals of those years, you note with amazement how gradually the names familiar to us disappear.

And this is the result. In the two-volume Geologicheskiy Slovar' /Geological Dictionary/, published in 1955, out of 12,000 terms not one is related to the problem of tektites. The Anglo-Russkon Geologicheskom Slovar' /English-Russian Geological Dictionary/ (1957) has only two words, and even one of these is a homonym: "australite -- a variety of obsidian from Australia," "moldavite -- moldavit (a variety of ozokerite [16])". Two words -- two errors. Even at the end of the 19th century it was known that australite is not obsidian. And "moldavite-tektite" is a name much more common than "moldavite-ozokerite". /50

But still the middle of the 20th century is marked by the vigorous growth of science and technology. Old physical and mathematical methods of research were perfected and new ones appeared. Laboratories were furnished with modern equipment -- high-speed, highly sensitive, and reliable in operation. Such scientific discipline as cybernetics, mathematical statistics, nuclear physics, and spectroscopy began to work miracles. Mankind enter the new era -- atomic energy, rocket engines, and space flights.

New personnel receiving their scientific training after the war and knowing nothing about tektites approached it in two ways. Some of them: devisers and publicizers of new methods and equipment sooner or later encounter the puzzling tektites in seeking subjects for investigation. Often curiosities emerged: some in describing specimens renamed the state of Georgia into Gruziya /Georgian Republic of the USSR/ [17], while others persistently linked moldavites with Moldavia; while still others called silica-glasses "tektites". Of course, there could be nothing in the way of serious theoretical conclusions here. But the science of tektites in this way received a mass of new, and at times unique analytic data requiring further generalizations.

The other approach was through astronomy. The translation into reality of the fantastic idea of space flights transformed astronomy faster than expected into a vital science, and astronomers from "fools not of this world" -- into the heroes of the day. And tektites again became the fashion: at first because everything related to space drew great attention; and then, because tektites were the only, besides meteorites, extra-terrestrial bodies, and to whom would it not be fascinating to touch (and all the more so investigate) stones that had flown perhaps from the moon!...

Two of the largest financing organizations in the United States -- National Aeronautics and Space Administration (NASA),

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[16] Ozokerite is natural paraffin whose deposits are found, in particular, in Moldavia.

[17] Georgia is an old name for Gruziya.

organizing the flights of the American astronauts, and the Atomic Energy Commission -- began to encourage the study of tektites. Tektite subject matter again began to flash on the pages of /51
scientific, and then popular journals. Astronomical, geological, and technological conferences included it in their agendas; and then even special conferences were organized.

But any scientific fashion does have its shady side. The problem of tektites, even though even in the most distorted form, appeared in the newspapers and in science fiction. Some authors sprinkled tektites as powder over the entire globe; while others plotted involved bands and zones. And tektites, Lybian desert glass, and impactites were all confused. They were ascribed enormous radioactivity and other improbable properties. The subject of tektites and living creatures from outer space came to light, a topic that could not be a scientific hypothesis owing to the poor knowledge we have of the subject and, therefore, owing to the absence of an explanation of existing facts. An example of the collision of a strictly scientific judgment with pseudo-scientific fantasy can be found in the series of articles in Literaturnaya Gazeta /Literary Newspaper/ and Komsomol'skaya Pravda /Young Communist League Truth/ on the following headings: "Traces Lead ... to Outer Space" -- "Traces Lead ... Into Ignorance," and so on. In the thinking of one such fantasizer, tektites were traces of earth probes made by astronauts from other worlds who hovered long over the planet in the same place(?) before landing.

Then the fashion raised the price of tektites among foreign jewelers, especially after world newspapers carried an item stating how the Duke of Edinburg had given his bride, the English Queen Elizabeth II a wondrously faceted moldavite. By its strength, clarity, and noble green coloration tektites actually stand up well when compared with other precious stones of the second class -- topazes, garnets, and chrysolites.

The First International Symposium on Tektites was held in Washington in 1957. Participants were mainly eminent experimenters, proposing new original methods for research on tektites; however, the problem began to be solved in a doubtful manner: as if there were no scientific heritage on tektites. Obvious facts and the latest laboratory results were presented seemingly over a void. Sometimes this method proved beneficial, for example, /52
in criminalistics. But in this case it did not give any results. Laboratory experiments were actually interesting, but the

conclusions obtained were cautious and cloudy; they could be reduced to the following: the origin of tektites thus remains unclear, but they obvious do have some relationship with outer space.

The results of four experiments reported at the symposium will be recounted in more detail.

Uranium in tektites. Apparently it was Leibniz who authored this aphorism: "The universe is reflected in a drop of water." In other words: in each drop or grain of sand one can find the atoms of all the chemical elements comprising the earth and the matter of the universe. This idea reduces to naught the task of qualitative analysis, requiring in the analysis of any material, instead of the answers "Present" or "No", the determination of even approximate quantitative relationships between constituents, and elevates the role of so-called trace elements up to the level of macroelemental (principal) composition. Today already many, even those not very familiar with chemistry, know of the great practical importance of trace elements, for example, in the life of animals and plants.

We wish to show by this that the fact of the discovery of uranium in tektites does not at all require that they be considered as possible atomic raw material. The development of a highly sensitive method of analysis made it possible to detect uranium in all specimens investigated -- from 0.00009 percent (or 9 mg per each 10 kg of material) to 0.0003 percent (or 3 mg per 1 kg). The exception was americanite from Peru (the americanite from Bolivia was not examined), containing 0.002 percent uranium, which proves the additional difference between tektites and pseudotektites.

Water in tektites. Thus far analysis chemists examining tektites approach them as ordinary rock. All rocks without exception contain water in their composition, averaging about 1 percent, and sometimes somewhat less. We know that the idea of "dry" and "wet" conditions is somewhat arbitrary, and absolute dryness does not exist on the surface of the earth. Moreover, even when heating an object, only part of the water and not all can be removed from it. Chemists know this, therefore they all "found" water in tektites as well. How this was obtained is a mystery to me. But the fact remains a fact: there is exceptionally little water in tektites -- on the average, 100 times less than in volcanic glasses, and 10 times less than in fused sandstones /53 resulting from the explosion of atomic bombs (atomic impactites). Ordinary quartz glass contains 0.02 percent water, while Czech "bottle stone -- moldavite -- contains up to 0.0005 percent (a level that is nearly impossible for terrestrial conditions). This discovery was one of the most sensational at the symposium.

Magnetic properties. We know that there is a direct link between iron content and magnetic properties. The famous Kursk Magnetic Anomaly, which sensitive airborne instruments have detected quite well, is associated with enormous bodies of iron ore. Iron is one of the most widespread elements in the earth, therefore it is equally difficult to find rock not containing iron and wholly devoid of magnetic properties. However, the manifestation of these properties can vary, depending on the state in which the iron is present.

The intensity of magnetization was determined, expressed in relative units:

tektites 0
Lybian desert glass 0
meteoritic impactite 0
americanite from Peru 3.8
obsidians, up to 1760 and higher

Heating to 1450° C reduces the upper limits of magnetization intensity for obsidians down to 15 and maintains the zero level for tektites. Again a conclusion suggests itself: in the formation tektites promptly underwent exceptionally high heating untypical for earth conditions.

Radioactive isotopes. Two scientists, Eman and Koman (each of these subsequently has added more than one page to the history of the problem), developed a method of determining radioactive isotopes: aluminum-26 and beryllium-10. These isotopes are found in meteorites and are formed owing to the extended action of cosmic rays on meteoritic material in outer space. But if these same isotopes were detected in tektites, their cosmic origin no longer was raised any doubt. And Eman and Koman did find such isotopes.... But the rejoicing was premature. First of all, further studies did not confirm their discovery. Secondly, all /54
determinations were made at the very limit of the method's sensitivity and only a rise in sensitivity could conclusively settle the question. Thirdly, it is not at all binding that tektites

must contain cosmogenic isotopes and have been in outer space for long time. If they were still not meteorites, then their cosmic history could be simply otherwise. All the more so in that their journey, for example, from the moon, was not so long....

You ask: what have Soviet scientists done in solving the problem of tektites?

The following chapter takes this up.

WE STUDY TEKTITES

First Words From the Geochemists. -- Mongolian Finds. -- How Important It Is to be Clean. -- Under the Electron Beam. -- "Cannon-Balls" in Tektites. -- It Is Hard to Determine Age, But It Is Possible. -- News About Petroleum.

Three famous academician-geologists -- V. I. Vernadskiy, A. Ye. Fersman, and F. Yu. Levinson-Lessing -- were the first Soviet scientists who were drawn to the problem of tektites. F. Yu. Levinson-Lessing -- a great expert on volcanic rocks -- additionally substantiated the existing differences between terrestrial and cosmic glasses. V. I. Vernadskiy and A. Ye. Fersman -- founders of the Soviet school of geochemists -- sought for relationships between terrestrial and cosmic matter, laying the foundation for new scientific disciplines -- cosmic mineralogy /astromineralogy/ and cosmochemistry /astrochemistry/. Therefore, tektites as possible strangers from the universe drew their special attention.

V. I. Vernadskiy laid the beginnings also of the first tektite collection in the USSR. On visiting France, he became acquainted with Lacroix and brought from him a large collection of indochinites, including fragments of the indochinite-giant "muong-nong" about the size of a large potato. The half-age of the specimens was obtained from engineer Hanus, and also from the Moravian Earth Museum and several private domestic collections. To them were added several dozens of philippinite pebbles and small stones. These several hundreds of specimens were exhibited in the display cases of the Mineralogical Museum of the USSR Academy of Sciences, now bearing the name of the talented scientist and popular writer A. Ye. Fersman, and became part of the famed meteoritic collection that has become the pride of the Soviet Academy.

The meteorite investigation, Professor I. S. Astapovich recalls how in his student years, in 1929, he gave a paper on tektites at a session of a mineralogical group headed by A. Ye.

Fersman: "The August meeting did not resolve to draw any specific conclusion except that the genesis (of tektites) was puzzling."

V. I. Vernadskiy understood that work on the problem of tektites in the USSR -- exploration and extensive laboratory studies -- was impossible without its broad popularization in the press. Before his death he assigned two of his students, the indefatigable investigator of meteorites, Ye. L. Krinov, to write a review, which then appeared in the magazine Priroda /Nature/ in 1946. /56

The first Soviet experimental studies were published at the very outset of the war, also with the cooperation of Vladimir Ivanovich Vernadskiy.

In the 1950's, after graduating from university, I worked as a part of a Soviet expedition in Mongolia. I was assigned to the position of head of the spectral laboratory -- a high-flown title and modest in staff. Attracted by the ideas of Soviet geochemists, I dreamed of converting this laboratory, resembling an old customs yard where small sandstorms cavorted, into a center for the study of minerals.

At that time spectral analysis was still a novelty, but it already promised great possibilities to researchers. We placed a speck of material, about 0.05 g, into the depression of a clean carbon electrode and fired a voltaic arc. The light passing through a system of lenses was projected onto a narrow slit, and then a quartz prism was put into position, and the light was then photographed on a plate as a narrow, 2.5-millimeter strip of spectrum. On the spectrum lines were easily discernible -- slit projections at different angles whose spatial position corresponded to a specific chemical element, and whose thickness corresponded to its concentration in the material being analyzed. Light metals yielded only a few lines, while heavy metals yielded many thousands. The spectrum of a compositionally complex material was similar to an opaque bowl, about which only an experienced specialist could not be confused (Fig. 24).

This was the first spectral laboratory in the Mongolian People's Republic, and in addition to expeditionary samples we also analyzed, on requests of our hospitable hosts, many of the most improbable things: helmets of the soldiers of Ghengis Khan, gold teeth turned green from copper impurities, and the dried

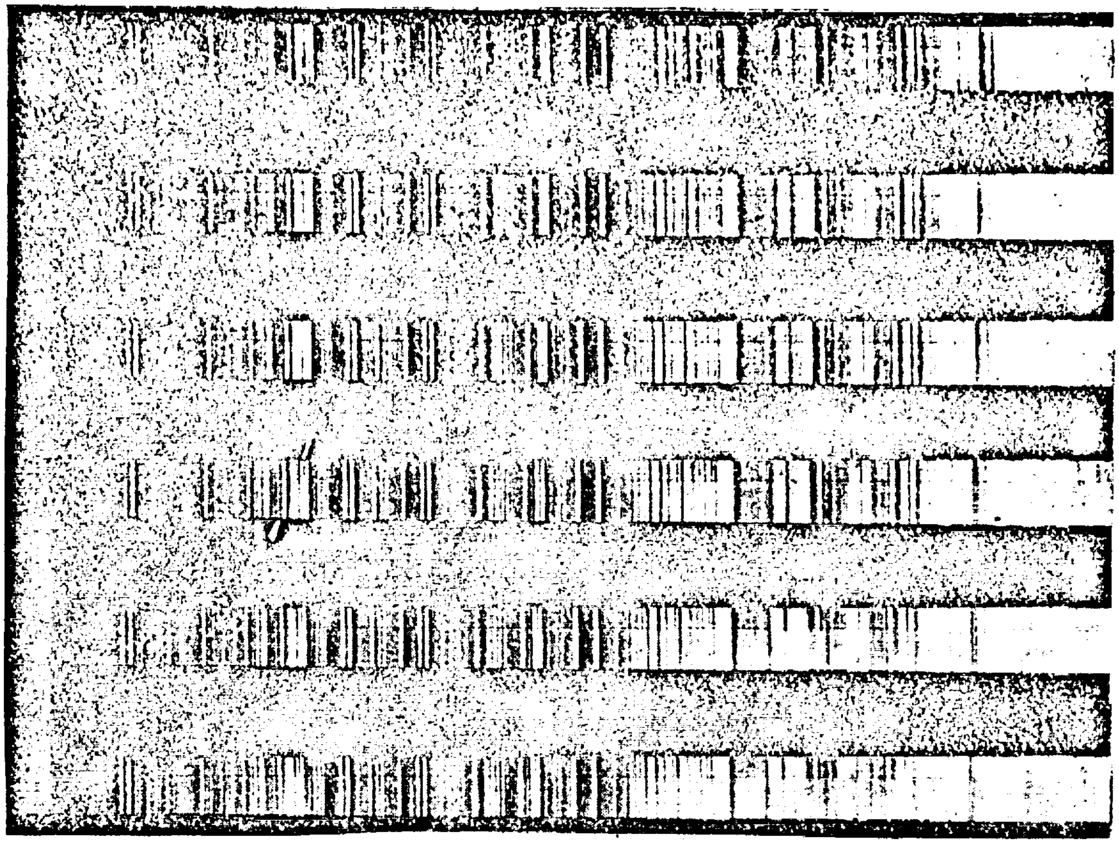

Fig. 24. Spectra of moldavites /57

feces of the Dalai Lama, brought by worshippers from Lhasa and apparently possessing therapeutic properties. We were visited most often by the Mongolian regionalist O. Namnandorzh. I practised the diagnostics of mineral materials and was elated each time when a determination of an unknown mineral was made /58
spectrally in half an hour instead of many days if old, classic methods had been used.

Once Namnandorzh sent for analysis pieces of a dark-green glassy stone. I at once set out to analyze it, but all my studies led me into an impasse. On spending an entire day, I was forced to recognize my defeat and wrote in the laboratory log "a streamlined" finding: " morphous substance of the type of volcanic lava." You ask: Was this tektite? I do not know. Then I did not know this word. And I recalled it only to show how easily an interesting object could pass by me if it did not lend itself to the commonly accepted method of analysis.

Together with Namnandorzh, we decided to carry out a joint study: to investigate in Mongolian museum meteorites, many of which were unknown to science. I already reported on the results of this work on my return to Moscow, at the All-Union Meteoritic Conference. The paper raised great interest and was criticized in that it spoke about the "Kerulenskiy meteorite." This slaglike mass, in spite of the recorded fact of its fall, actually differed greatly from known meteorites that in general are similar in composition. In the course of the discussion, I learned about tektites for the first time and, on insisting on the extra-terrestrial nature of the "Kerulenskiy meteorite," I posed a question to my opponents: perhaps this is tektite? -- not suspecting that the discovery of tektites in Mongolia would be a genuine sensation.

Wishing to become more familiar with tektites, I turned to the learned secretary of the Committee on Meteorites of the USSR Academy of Sciences, Yevgeniy Leonidovich Krinov. He showed me his collection materials and literature and proposed that spectral analysis be used to investigate first several specimens of indochinites, then moldavites, and then that I write a popular article, scientific review, and to give a response about one study. Thus, unbeknownst to me and to others I acquired the reputation of a specialist on tektites.

On my return from Mongolia, I was assigned to one of the Moscow petroleum institutes and the study of tektites to which I had been giving increasing attention, was not very compatible with /59
the subject matter of my principal work. Once in order to develop a technique for the high-sensitivity analysis of tektites, I had to justify the development as applied to petroleum. It actually proved useful for petroleum, but petroleum specialists still did not know who was the perpetrator of its birth.

Each new tektite analysis was a great event for our young collective. We valued very highly the tektite material which we obtained from Ye. L. Krinov in the form of tiny crumbs.

The actual method of analysis caused us a lot of troubles. In one sample of the material several dozen of elements were determined simultaneously in the most disparate concentrations -- from several percentages to millionths of a percent. To do this, we prepared reference standards containing, successively, 1 percent, 0.1 percent, 0.01 percent, 0.001 percent, and so on of the sought-for elements and recorded their spectra on the same photographic plate. But we had to battle for each new, lower concentration level. Sterile cleanliness began to be observed in the laboratory. All kinds of things had a bearing on the analysis! A vehicle passes along the street leaving behind it exhaust gas smoke, and immediately the lines of lead appeared in our spectra. One flight above tables are moved around -- and particles of plaster from the ceiling produce the lines of calcium in the spectra.

We painted the walls and ceilings with oil-based paint. We sealed the windows tightly, in spite of the summer heat. Before each analysis we carefully washed our hands.

But the battle for purity was not limited to this. It was decided to use as the diluent-powder for the reference standards and extremely pure quartz -- rock crystal that I have brought from Mongolia and which differs little in its properties from tektite glass. But still it contained many trace elements of all kinds, and the spectra of reference standards with concentrations below 0.001 percent differed hardly at all from each other. We had to find another, purer substance and used it to dilute simultaneously tektite powder and the reference standards. The physicists said that nature abhores a vacuum. The same can be by chemists about sterility. Ultrapure materials are not found in nature. This means that they must be obtained artificially, in laboratories. But obtaining such synthetic material is still not the end of it. We had to see that in its dilution it did not extinguish the lines of elements in spectra, since a reduction in the concentration of impurities and additional dilution /60 could bring to naught the effect of the high-sensitivity analysis.

After long searching, we found such a diluent. It was lithium fluoride, which when used to dilute a material several times preserves line intensity and even enhances it for several elements. We mixed a sample with lithium fluoride and pure carbon powder (for combustion stability) and photographed it in two diluent variants in order to separately determine the content of macro and trace elements.

The next stage of the study was a further rise in the sensitivity of analysis by varying the electrical regime, electrode shape, sensitivity of photographic plates, and the conditions of their development.

But when we sensed ourselves to be masters in the field of concentrations of ten-thousandths and hundreds-thousandths of a percent, yet another obstacle came to light: in addition to increasing the line intensity in samples and reference standards, the intensities of the lines of ultratrace impurities of lithium fluoride rose excessively -- alkali and alkaline-earth metals began to show up; the intensities of previously invisible lines of lead began to be equivalent to several percentages of this element under ordinary condition; along with lead, its invariant trace accessory -- silver -- appeared. We recognized ourselves as defeated with respect to these uninvited guests, but gained an important advantage for another 10-20 elements. A special effect was produced by the rare and light metal beryllium, whose content is very exactly determined in tektites, silica-glasses, volcanic glasses, and even in ordinary champagne glass bottles.

Thus we worked from day to day, penetrating the secrets of tektite material. The high-frequency voltaic arc buzzed smoothly, instantaneously transforming into vapor even the most refractory materials. But its blinding-white flame could be looked at only through completely dark glasses. High-temperature physicochemical processes similar to the processes of tektite formation occurred in the electrode crater, as if in the crater of a volcano. The fume of the toxic combustion products streamed over the crater -- carbon monoxide, cyanide, and other products, exiting into a powerful forced-draft unit.

The red eye of the generator winked. Laboratory assistant Tamara skillfully took the next spectrum photograph....

The South African scientist S. Taylor, the American A. Cohen, /61
and others joined our relay-race in the study of trace elements in tektites.

And this is what ultimately began to be known about the chemical properties of tektite material. In its composition it is a solid solution of various oxides of metals in silicon oxide. In some tektites silicon is contained in somewhat greater amounts, and the other metals -- in smaller amounts, while the opposite is the case for other tektites. In not a single terrestrial rock were these regularities found.

On text page 37 /translation page 32/ we wrote about the features of the composition of acidic, medium, basic, and ultrabasic volcanic rock. Extending the series, we can cite the meteorites of super-ultrabasic rocks. But where do tektites fit in? In their principal composition (macrocomposition), these are typical acidic formations, but as to the composition of trace elements these are basic and ultrabasic materials, and even meteorites. The ratio of nickel to cobalt -- element congeners very frequently present together in terrestrial conditions -- is a singular dissonance. Nickel is contained in tektites and meteorites at a much higher level than is cobalt.

Each terrestrial rock has its own quite extensive variations in composition. In particular, meteorites differ widely from these rocks in that their composition fluctuates but very little. Tektites are intermediate in this respect between meteorites and terrestrial rocks.

Within the limits of each tektite strewnfield, the composition of tektites varies in a definite manner, independent of the composition of the geological deposits where they are found. Tektites contain extremely little volatile constituents. Moreover, volatile constituents are found at a much lower level along the margins of preserved specimens than in their bulk.

The conclusion is: chemically, tektite material is either of cosmic origin, or was formed in a complex cosmogenic process of the mixing of terrestrial objects. In both cases their formation was preceded by intense heating.

Alongside our spectral laboratory stood an electron microscopic laboratory. Engaging in preparing the next sample of indochinite for analysis, I decided to examine it first in the electron microscope. This was not a modern miracle-instrument magnifying by hundreds of thousands of times, for even we did not require this magnification, whose degree was limited by the degree of powder grinding ("to the state of powder").

One after the other there flashed on the blue screen pictures with configurations of the tiniest particles of tektite embedded in

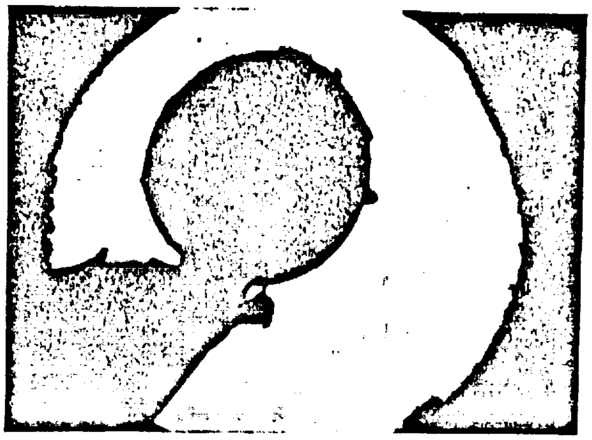

Fig. 25. Tiny sphere of indochinite in the transmitted electron beam of an electron microscope. Magnified 5000 times. /62

collodium on a thin, quite even, linenlike, metal grid. An electron beam passing through a grid cell illuminated the free space on the screen, leaving the edges of the cell and the tektite particles in black -- oblong, with sharp edges and rounded ends. These particles differed in almost no manner from large glass fragments visible by the naked eye. True, the mechanism of the failure of glass with particles ranging in size from centimeters to microns remains the same. But here on the screen their flashes and disappears a completely regular sphere. We attempt to find it in order to examine it again, but it does not appear. The path from one end of the cell to the other was infinite and thousands of tiny tektite particles could play hide-and-seek with us. We thus did not find the sphere, but on the other hand we then encountered many others, establishing that they are quite typical of the microstructure of tektite glass. Their dimension varies from tenths of a micron to 10 microns (Fig. 25).

What could this be? The microscope shows only the shape, and we did not have at our disposal an instrument that would at once determine the composition. Perhaps, these are extremely tiny spheres of nickelous iron which are so numerous in meteoritic impactites?...

A year passed, and again I am sitting in the laboratory deserted at the end of the working day. The switches are off and the instruments painstakingly covered with white hoods have been removed. Beyond the door are the barely audible steps of the fireman. I prepare for the analysis of a philippinite specimen. Tektites have many amazing properties, one being strength and brittleness simultaneously. Armed with a hammer and a small chisel, I attempted, without damaging the specimen, to chip off the fragment I needed. You strike the glass -- no result. You strike harder and you can ruin the entire specimen. It occurred

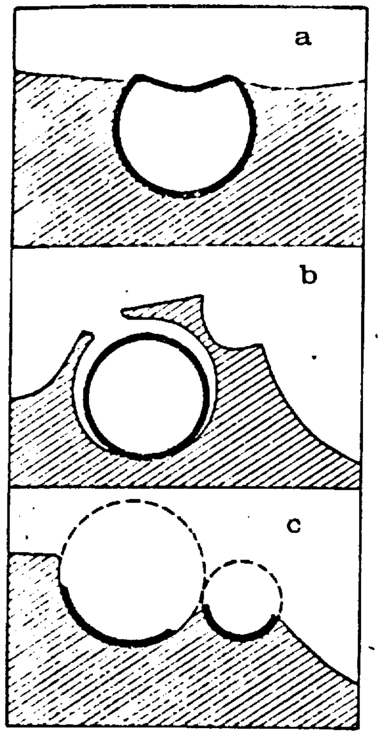

Fig. 26. Hollow tiny iron sphere at the surface of philippinites /63

to me: why not chip the thin crust from the tektite surface and a crumblike metal sphere can be visible in the fresh fracture. It is 1.9 mm in diameter and was similar under a strong magnifying glass to an old cannonball that had been pitted with rust. Armed with a needle, I began to investigate the surface. Incautious pressure and a breach forms in the sphere. And this is what it is: it turns out that the sphere is hollow. The wall thickness scarcely exceeds 0.1 mm, but it still a sphere, and yet....

The next day I visited the Mineralogical Museum. I asked for the collection of philippinites and began a second, closer study. So it is -- even here, true, in not all specimens, but in one I counted several dozens of semispherical depressions. Spheres 1.5-2 mm in diameter sit in many /64
depressions. Several of these can be easily extracted with a needle; others sit more than half submerged in the tektite mass, but can be rotated in their setting (Fig. 26). Why then did no one see them earlier? Incidentally, I myself would not have noticed them if it had not been a happy accident. They are like mushrooms: you see one, and then after it a whole family. I sacrificed one of the spheres for spectral analysis. The lines of iron and very faint lines of nickel appeared in the spectrum.

The report about the discovery was published in the journal Doklady Akademii Nauk SSSR /Reports of the USSR Academy of Sciences/. It was immediately reprinted in the United States in order to familiarize tektite researchers usually poorly informed about advances in Soviet science. A group of American geologists decided to repeat these experiments. They examined their philippinite collections and deep in one specimen found a fresh unoxidized sphere 0.1-0.5 mm in diameter, which consisted -- from the data of precision x-ray diffraction analysis -- of typical meteoritic minerals unknown on the earth -- nickelous iron (kamacite) and iron phosphide (schreibersite).

A plenum of the Committee on Meteorites of the Ukraine SSR Academy of Sciences on the problem of tektites was held in Kiev in May 1961. It was still quite popular in orientation, but to some extent served as an impetus for advances in research in our country and the organization of new research centers. The Geological Institute in Kiev (the Committee on Meteorites of the Ukrainian SSR Academy of Sciences) became one such center on the study of physical properties of tektites.

Another center emerged in Leningrad based on the Radium Institute under the leadership of Corresponding Member of the USSR Academy of Sciences I. Ye. Starik, who set as his goal investigation of the isotope composition and age of tektites. Direct laboratory studies were headed by the talented young scientist E. V. Sobotovich.

As we know, geological age is determined by the relative occurrence of rock layers and the rate of their deposition. But at present more precise radioactive methods are being successfully employed, based on the fact that after the formation of a rock the radioactive isotopes it contains begin to decay; by knowing the decay rate and the amount of products accumulated, one can calculate /65 the age of the rock overburden. Figures obtained by this method confirm and revise geological data, with the exception of the cases when due to the action of external conditions the rock can be modified and lose some of the decay products of its radioisotopes. Then the radioactive method determines not the absolute age of the rock, but the time elapsing after its modification.

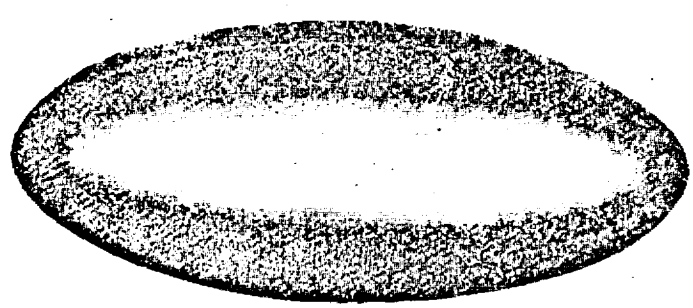

Fig. 27. Gaseous inclusion in moldavite. Magnified 120 times.

The first age determinations for tektites yielded improbably contradictory data -- from a million to several billions of years. Researchers simply threw up their hands. But time passed; physicists of the Federal Republic of Germany and American scientists took part in the work, and the picture began to clear up.

Since tektites in their fall on the earth underwent secondary melting, most of the isotopic determinations usually fixed this time -- the terrestrial age, and not the cosmic age of the material itself. It is not yet possible to determine the terrestrial age very precisely, since tektites have different degrees of modification. The youngest are the australites -- they fell half a million years ago, and perhaps, even tens of thousands of years ago, that is, when man already existed. The ages of the billitonites, javaites, indochinites, and philippinites are the same and are quite close to the age of the australites.

The tektites of the Ivory Coast are more than one million years old, moldavites -- 15-20 millions of years, and the North American tektites -- more than 30 million years. The most ancient is Lybian desert glass: 70 million years.

Therefore, tektites fell on the earth several times.

The year 1965 signaled a new discovery. It was made in the youngest center of tektite research -- Kola Branch of the USSR Academy of Sciences. /66

There, beyond the Polar Circle, a small academic community stretched along the foothills of the Khibinskiye Mountains. It had not yet been named, but among Kola geologists it was known as Fersmangrad. On the largest ore-chemical industry there grew up a major scientific base, whose importance has long since outstripped its territorial setting.

The laboratory of I. A. Petersil'ye investigating organic matter in rocks is one of the cottages of Geological Institute of the Kola Branch. Quite recently it was believed that organic matter cannot be present in volcanic rocks. The Kola scientists were able to refute this assertion.

In many tektite specimens very large gas bubbles, sometimes several millimeters in diameter, can be found (Fig. 27). They consist nearly entirely of carbon dioxide -- carbon dioxide gas, whose total volume is 1 cm^3 per 10 kg of tektite glass. When these bubbles were investigated, scattered inclusions of petroleum bitumen were detected. From a 200-gram weighed sample 13 mg of bitumen were able to be extracted and analyzed.

Organic matter! About ten years ago this would be a series of argument in favor of the terrestrial origin of tektites. But today? The cosmic origin has been basically already proven. Then is not this evidence in favor of the origin and development of life in outer space? Or else could petroleum also be inorganic in origin, and its birthplace -- not only the earth? Here truly is another scene for science fiction writers!

Now the Kola scientists began their program of more intensive studies of tektites, including their physical properties and the isotopic composition of bitumen carbon. The method of integrated study of physical properties developed here for the first time can already be applied to small samples of lunar rock which astronauts will bring us. A general repetition of these studies will be carried on tektites.

We are at the threshold of new discoveries.

Letter With a Big Stamp. -- Children's Contribution to Science. -- Where Schweik Was. -- Television Report From the Spring Fields. -- Outer Space Is Accessible to All. -- Guests of 15,000 Moldavites. -- How the Czechoslovak Shower Fell

Several years ago I was sent a letter with a large Czechoslovak stamp on a worn envelope. The letter had travelled far through the institutes of Academy of Sciences in search of the addressee. It was sent by members of an astronomy group of youth in the regional public observatory of the city of Ceske-Budejovice in order to establish with me and other Soviet scientists studying tektites fraternal ties and to render as much help as possible in studying moldavites in their country. At the close of the letter was the small imprint of the observatory and an enormous, almost covering the entire sheet, imprint of the group -- bearing stars, Saturn, and a rocket flying to it.

Thus our friendship of many years was forged, and as a result the conditions under which the Czechoslovak tektite shower fell were clarified and the front of laboratory work based on specimens collected by group members was extended.

On Sundays, group members set out in a noisy throng in search of for tektites, since they are found everywhere, even in the city itself. On holidays more wide-ranging hikes are arranged, with nights spent sleeping in cots and under the open heavens. The hikes are festive in character. Ahead marches the monitor bearing the group's pennant, and behind him in pairs, in threes and in fours -- the youngest, and at the end -- the older teenagers, bearing heavy packs on long poles. The burning summer sun, autumn showers, and spring frosts do not perturb the young pathfinders. In front of me are dozens of photographs -- documents of the interesting hikes. Here it's one of them: on a field at the edge of a forest from which the snow has not yet retreated are assembled youngsters around a smoking fireplace, the youngest of which is scarcely nine. The fire has not yet flared up and the children are seated, hunched closely, and obviously silent. And here is another photo: everyone is dispersed over a field, but someone had a misfortune --

a wasp had stung him and he, almost about to cry, is throwing off his trousers while he smiled broadly. But best of all is one showing them on a sunny spring day during a halt: someone singing /68
songs, others are gathered at a map with the scale of two versts /3500 feet = 1 verst/ to an inch, are running their fingers over it, and are dreaming of even longer hikes, and someone else is playing the jester. Another is lying in the grass, dreamingly glancing at the sky. The group leader, Comrade Gustav Shkrov imperturbably smokes his changeless pipe and his eyes smile.

Shkrov is aided by two more adults: Zhila -- a teacher, and Kubichek -- an agronomist. It is good to have your own agronomist in the group! He readily finds the way to the heart of the peasant and then the farmer eagerly feeds the spring travellers, offering them lodging for the night and advice on where to best look for tektites.

The program of studies sent me included the recording and entering on the map of all places of tektite finds, a description of these "deposits", a recording of specimens and their statistical interpretation, a collection of folklore data, manuscript and printed works, and familiarization of the population with this program.

The children went through freshly plowed fields, visited all new sand pits and irrigation structures (Fig. 28), dug excavations themselves and sieved rock (Fig. 29), questioned local inhabitants, set up friendships with their children, inspected private collections, and spoke over the radio. From 1962 to 1964 the group members visited 56 "deposits", discovering 19 of these of these for the first time and compiling schematic plans for 51. Two reports on these efforts were published under the collective authorship of the group in the periodic collection of the USSR Academy of Sciences *Meteoritika* /Meteoritics/.

Once a jovial and mop-headed member of the group -- Martin Brems -- sent me a letter and then himself visited me in Moscow. This youngster was a jack-of-all-trades: he had photographed two art films, had performed in puppet shows, draws well, made engravings on linoleum, collected stamps and emblems, and was studying the art of fencing. Moreover, he had rich experience concerning tektites. In Moscow when he was not laughing, he looked serious and very effective in his Pioneer uniform with many insignias and emblems, drawing the attention of passers-by and especially of his Soviet peers. He made a gift to the Museum of Moscow

University of a beautiful moldavite specimen, and received in return the gift of volcanic sulfur from Kamchatka.

And, finally, I myself visited Ceske-Budejovice on the official invitation of the group. ("Ceske-Budejovice? One of my /70
acquaintances asked me in amazement. "Then Gashek really didn't dream this up?" -- Later I recalled this many times, and my Budejovice friends laughed as over a joke.)

Fig. 28. A just-dug irrigation canal. The youngsters are digging spoil banks. Dol'ni-Svintce. (photograph: M. Tuma) /69

Fig. 29. Sieving tektite-bearing sands on the bank of the Bezdrev

... The tourist season had not yet begun, and I am seated in the empty cab of a half-empty wagon with a map of South Czechoslovakia on my lap, I am mulling over the plan of the forthcoming routes and meetings with local regionalists, I am reading the history of Czechoslovakia, and questions are swarming in my head. Why, for example, has no one written the history of Czechoslovak tektites? ... The Luzhis, the Celts (Gauls), the German tribes, the Slavs --What did they know about tektites? ... Libraries, archives, museums are silent. But in South-east Asia -- a region of jungles and fever -- legends have grown up about tektites, they have been collected, used in rituals and as decorations. One must speak with geologists, question historians, ethnographers, and experts about the old and new Czech culture....

... The cherries are blossoming in Prague. I meet with Gustav Shkrov, Martin Brems, and Mikhail Tuma -- a young photographer, who was then recording our tektite hikes. Gustav had a fast youthful step. Twenty years ago he had been a partisan and had fought together with Russian soldiers escaping from prison camps. Gustav spoke a little Russian and this must be of assistance in our work.

But how Martin had grown! Only two years had gone by, and he was already a full-grown man, he had received his passport, he was making his way, and he was deciding the question that is common to his age: What to be.

That evening we sat in the rail car of an inter-county train "Prague - Ceske -Budejovice." Our destination was 150 kilometers away in the direction of the Austrian border. Already at twilight we arrived at Tabor.... We reached Ceske-Budejovice late. I was noisily greeted by the youngest members of an astronomy group.

The city had prepared to commemorate in 1965.its 700th birthday. I remember the central square with a statue of Samson, surrounded by medieval three-story houses with porticoes.

Gustav lived in a new city, in a large multi-colored paneled home. At the wide glassed-in door were the buttons for ringing all the apartments. In the first, ground floor there was a large lobby with mailboxes for letters, milk, and bread, a room for perambulators, and automatic washer, drier, and ironing machine. At the stairs to each door were personal shoes. Gustav apologized /71
for the disorder, explaining it by the fact that each apartment had children, and as a way of checking he made a microscopic scratch in the bright-red elevator.

That morning I was awoken by some kind of mysterious hubbub. Three young occupants of the apartment had gathered at the keyhole:

Should they go against what their parents had said and open the door or should they wait until the "pan" from Moscow woke up and invited them in himself. I did not understand their language and more properly guessed what they were saying from the tone of the conversation, which is the same for all children anywhere.

Seven o'clock. I got up from my featherbed and opened the window. The sun gilded the tile roofs of the home, between which the white smoke of a suburban train wandered. Faraway were blue hills, and still further -- the city of Klet with a television tower and the dome of the astronomical observatory.

We were in the center of the South Czech tektite region and on many days Shkrov's apartment became the headquarters of the expedition. One of the "deposits" was in the city itself and had yielded to the National Museum in Prague more than 100 specimens. We -- tektite researchers -- used the word "deposit" not in the ordinary geological sense, since tektites are not ores and hardly at all form local bodies. The name is given based on the nearest inhabited place, and the hundred tektite deposits now known is quite an arbitrary number.

From my window I saw the section of another deposit -- Mlade, near a village of the same name 2 kilometers away from the city. Here in a small sand pit ("piscarne") the group members last year had found one specimen and had sent it to me.

The county public observatory was located in a picturesque place -- by the compass, at the junction of the rivers Vltava and Mlade (Fig. 30). Most of the time this observatory was given over to children. They measured the coordinates of the stars and studied eclipses of the sun, moon, and planets, the movements of artificial satellites, and designed themselves uncomplicated astronomical instruments. The last three years they were also occupied with the problem of tektites.

Everyone gathered at the observatory balcony, drowning in flowers. At my appearance an improbable noise arose. But now it was noisy here not only because of the children present. Representatives of newspapers, local radio, and Prague television had arrived. In Czechoslovakia, tektites are of interest not only to scientists but they are also a unique sightseeing attraction of the country. The arrival of a Soviet person is not a very common event in this quiet city, all the more so in that he is associated with a program of joint research. This interesting friendship of

Soviet scientists and Czech schoolchildren has been written about in Nauka i Zhizn' /Science and Life/, Yunyy Tekhnik /The Young Technician/, and even more extensively -- by Czechoslovak newspapers and magazines.

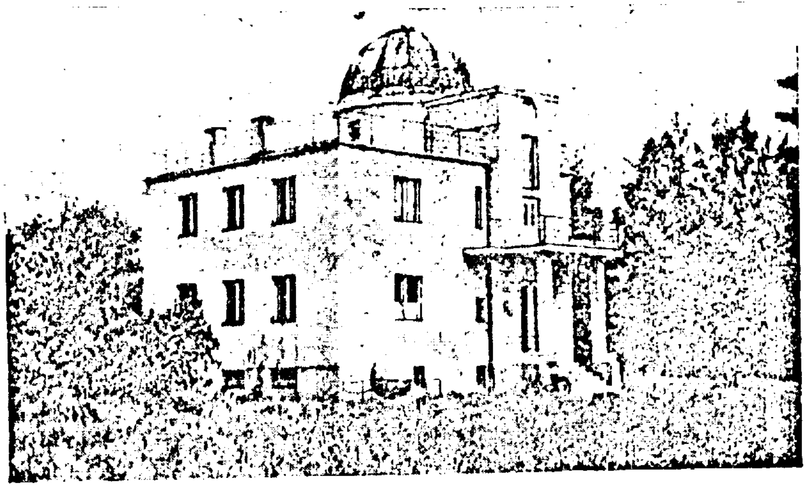

Fig. 30. County public observatory in the city of Ceske-Budejovice /72

Greetings, numerous interviews, and interruptions.... After inspecting the observatory, together with the children we entered automobiles offered us by three groups of editors -- newspaper, radio, and television, and set off on our first "official" hike, which with all details would be recorded on film and shown in part in the latest news from Prague, and in full -- in the May First youth broadcast.

The noisy line of cars left the place and headed toward the two richest deposits, which had accounted for many thousands of finds -- Vrabce and Koroseki.

There was a small stop in Vrabce. We took on one more passenger -- 13-year-old Jan Pitalek, whom the group members had jokingly /73 called their "political affairs editor" in the village. Only recently Jan had found 55 pieces of tektites in a freshly plowed field, known here under the name of Nova-Gospoda. They were all mainly small fragments of primary forms. Here is what one of them looked like: very much like the shell of a walnut -- rough exterior and smooth interior. Several tabular convex-concave specimens -- resembling pieces of broken glass tubing. This has the form of a vertebra and has even the base of one rib. And here are more specimens -- a tonguelike piece and a sausagelike tektite, neat, as if cut into slices with a very sharp knife. Who can puzzle out the mystery of these uncommon shapes?!

Vrabce is a small village. A tiny little chapel -- the "little drop" -- with a statue of the Madonna, a public square that is a scaled-down copy of the central square in Ceske-Budejovice. Tidy white houses under groves of powerful trees. We toured the village and stopped in the field. Everyone rushed out of the cars with screams and laughter. There were many reasons for the children's glee, one of them (although not the most important) was that today they did not go to school and would receive their vouchers in the observatory.

The field had been recently plowed and fertilized. After heavy rains it had been soaked and our routes rapidly became muddy.

The participants on the hike arranged themselves in a long file and began to comb the field. Here, amidst milk-white quartz pebbles, rust-brown concretions, and fragments of old-Slavic and Celt ceramics and droppings sometimes tektites had fallen. It was not a great misfortune if the untrained eye initially mistook as a tektite a goat's green "nut coal" /droppings/. In low places and sandy chestnut soils pebbles and tektites are found somewhat more often than in other locales.

The first success was gained by veterans of the group and tektite hikes -- Brems and Koudelke. One of them found a splendid tektite, resembling in shape and size a dung beetle.

The excitement of the search gripped everyone, even the journalists, who for sometime forgot about their main duties. Soon even I found a tektite.

Gradually the file broke up and now motley-colored figures flashed over the entire field. The peasants had long since grown accustomed to such doings and quite often hunted for moldavites themselves.

The signal is given -- back to the cars. We counted our trophies: seven specimens. One of them is very much like a beetle, another is more like a spruce cone, while still another is quite like a flat drop....

Fig. 31. In the "piscarne". At the right -- Jan Pitalek /74

Then we passed through a fir-pine grove and came to a large almost circular "piscarne", several meters in depth. Here there were also tektites. We carefully studied the outcropping, but we were not lucky: a bulldozer had been here recently and had levelled the richest places.

A halt. The children gathered dry pine branches and a hot bonfire is blazing. During supper the children succeeded not only in putting to me numerous questions of the most varied kinds but also in exchanging with each other stamps and match books. They studied Russian in school, but their successes scarcely surpassed the successes of Russian schoolchildren sweating over German or English. The absence of conversational practice became evident. "How many years have you studied Russian?" I asked the youngest one. "Thirteen years," -- he answered, and only a few noticed the error /the error in the child's answer was that the plural form of the word for years rather than the special singular form was used. -- Translator/.

On the following days we made trips in the rail cars of the suburban line to two other sightseeing points -- Gluboka and Ceske- /75 Krumlov. In Gluboka I became acquainted with the first "piscarne" -- a lake, more properly, a pond -- one of two thousand artificial lakes in South Czechoslovakia. The trees along the banks stood in water and bowed their crowns sharply. White gulls screamed loudly.

Before the revolution this part of country belonged to the German barons Schwarzenberg, who, as they said, laid down the beginnings of the pond economy. Once every three years the water in each pond was lowered and all the surrounding populace took part in gathering fish. During this time it was very convenient to collect tektites as well. But the group members, not waiting for the schedule, organized entire underwater expeditions with slippers and aqua-lungs. Six kilometers from Ceske-Budejovice, at the bottom of the vast (522 hectares) Bezdrev pond they found many large specimens, which were dripping with water to the extent that they could not be distinguished from ordinary pebbles. On being examined in the light, large bubbles could be seen in them; these gaseous inclusions were then examined at the Kola Branch of the USSR Academy of Sciences.

The fabled Neo-Gothic castle of the Schwartzenbergs -- Gluboka nad Vltava -- soared amidst powerful oak trees and plane trees.

And yet another monument to the past -- of the few well-preserved Gothic cities -- Ceske-Krumlov. We travelled its narrow and steep nooks as guests of Josef Prokopets -- one of the amateur collectors of moldavites. He lives in a home built in 1570. Strong, meter-thick walls. On a small stairwell there hangs a modern print. The door opens, and we entered a comfortable, tastefully furnished apartment. Gothic items are sensed everywhere -- in the heavy vaults of the ceilings, the large tiled oven, pillars, and steep tiled roofs extending beyond the window, but combined quite amazingly with modern style.

Prokopets is a lathe operator ("an observer"), a member of the Czechoslovak Astronomical Society, a leader of the local astronomy group, with the high city tower at his disposal. Together with his wife, son, and sometimes also with several members he covered a total of 4500 kilometers on his motorcycle in a total of 54 days, visiting up to 60 deposits. The year 1964 was especially rich for him -- 1500 moldavite specimens weighing from 0.1 to 71 grams. A unique record was set in the area of Kosov-Milikovice, where in /76
two and half hours two persons found 59 specimens.

Prokopets conducted the following experiment. Close to the same location of Melikovice, he and his wife literally combed a field with an area of 250 x 80 m over a period of eight hours, covering 20 kilometers. Each find was entered on a map. As a result it was found that tektites were unevenly distributed over the field, and in one "nest" 30 m in diameter the couple found 23 tektite specimens together with 1200 well-drenched pebbles 2-4 cm in diameter. The haul from the remaining area of the field yielded 30 specimens. In three days this "nest" was visited by another tektite collector and 12 more specimens were found.

We spent five hours together with Shkrov studying the collection of Prokopets, estimated to be more than 2000 tektites. This was far from all the material that the worker-enthusiast had collected. Many of his specimens are stored in the National Museum in Prague, in the museum of city of Ceske-Krumlov, among group members, and many have been given to various investigators, including persons from abroad. Prokopets has built up ties with many famous scientists, obtains literature from them, obtains tektites from other countries, and experiments on his own. He showed me interesting objects on several specimens that had been previously unknown to science -- very tiny needles on the surfaces of specimens that resemble druses of quartz.

The program of our expedition included not only field geological work, but also examination of state and private moldavite collections. The second largest private collection was in Ceske-Budejovice belonging to a professor in a secondary school, Doctor Jan Oswald -- one of the classicists of tektite science. During the years of the Fascist occupation he was able to print a well-illustrated monograph *Meteoritnoye Steklo* [Meteoritic Glass], which has not lost its scientific value.

Jan Oswald lives in a large old house. A statue of the Madonna stands in a stairway niche on a clean towel. In the apartment everything harks back to past times: bronze, Gobelins [tapestries], and paintings by famous masters. We met the 75-year-old professor together with his son. He keeps a unique collection, which he has gathered over many years -- 3900 carefully selected moldavite specimens in a large polished cabinet with many sliding doors. They [7]
include truly unique items: a perfect disk 6.5 x 6 x 1.2 cm in size from Lgenine, the largest specimen (87.5 g) -- from Slavce, and so on. Oswald is the actual founder and keeper, for many years, of the state collection in the regional museum of the city of Ceske-Budejovice.

The meeting with professor was somewhat official in tone, resembling a diplomatic reception. Shkrov surpassed himself as an interpreter. I learned that Oswald was born in Gluboka and during his student years at Karlovy University learned about the problem of tektites, on being present during a collision of two contradictory points of view about their origin. Later, as a teacher in a realgymnasium, he began to study tektites independently, looked for new deposits, and investigated old locations of finds. In Prague, Osvald came to know Hanus, already familiar to us. Being an engineer, Hanus had built sugar mills in pre-revolutionary

Russia and, on retiring, had been fascinated for many years with geology, had collected trilobites [17], and then had turned to tektites: he had given the National Prague Museum 10,000 specimens, thus actually laying the basis for this unique collection.

On 20 April we began our fifth and longest route in South Czechoslovakia. The car was driven by a father of one of our youngsters. The ribbon of highway stretched to the south, passed sparkling clean little homes, roads through the hills, disappeared in small groves, and many times intersected the same stretch of railway. Motor tourists from nearly all countries of Europe passed us going the other way.

The names of villages flashed by every minute. It was worth digging through the road map as if you had let something interesting go by.

The first large populated place was Kamenni-Uyezd. The signpost warned that it was 87 kilometers to the Austrian city of Linz. On both sides of the road were tektite-containing fields: Ranchice, Milikovice, Kosov. Near Kraseyovka we pulled over to the side, stopped the car beyond the village, and entered the field. Our attention was drawn to an irrigation canal. In its bank we saw /78 clay, sand, pebbles, and old bits of pottery. Here at once after completing their work the group members found several beautiful moldavites.... White mounds of chemical fertilizers prepared for application to the soil lay on the field. Imperceptibly we had passed over to the territory of another deposit -- Dolni-Svince. Here, unexpected to myself, I found a tektite -- a small broken little rod, like a candy that had been licked. Everyone was swept up by the excitement. Then we entered the village of Dolni-Svince and asked at the home of peasant Shtepan -- a local tektite collector.

An empty spacious anteroom. A large living room, and behind it -- another room. Broad, city-type windows. A sideboard, television set, and radio. A baby was crying in a tall wooden crib. We greeted Shtepan and his family. The hosts were flattered and very pleased; they wished to speak about a great deal and question the first Russian person who has visited their home. Expansive Shtepan brought out a large box containing tektite specimens,

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[17] Trilobites are fossil arthropoda.

unexpectedly dropped it; we crawled along the floor collecting the scattered specimens while the child cried lustily. During the conversation the host rapidly jumped from the subject of the rate of work-day remuneration in the collective farm to archaeology, which he was pursuing, and freely used such terms as "Tertiary deposits" and "before our era." He instructed us when and how best to collect tektites and, moreover, recalled that in his childhood he knew them under the name "bride stones."

In half an hour the car again rushed us southward. We drove beyond the limits of the tektite region. The composition of the rock and the soil type changed. The number of recorded finds steadily decreased here. We sensed the closeness of the mountains. The car made a sharp turn, skirting a hill with a Roman Catholic church and a monastery at its crest. Suddenly a sharp right turn: ahead of us was a road barrier, sentries, and several waiting buses. The state frontier. Beyond the second barrier was the Austrian side and Austrian sentries. We sat for some time beside an empty, plowed field. Then the frontier posts moved away to one side. The picturesque mountain tract of Central Europe -- the Shumava -- began. The road climbed, and from afar off we could see the place where the Vltava made its famous abrupt 90^{o} turn -- from east to north. White specks of grazing sheep were scattered along the mountain slopes overgrown with a fir forest.

Fig. 32. Guess where the moldavite is here? /79

The next stop was at Louchovice. A large cellulose-paper combine.

In one of the shops of the combine production of a completely different kind has taken shelter: an electric furnace several meters high; here large mirrors are cast for telescopes, which are not inferior in their qualities to

Zeiss mirrors. The team was headed by the hereditary worker Ergart, a passionate lover of astronomy, who had written together with his brother a number of special books and who had published, among other things, a very popular photographic album for tourists, Po Yuzhno-Cheshskomu Kray /Through South Czechoslovakia/. All his free time he spent in this shop. The plant director assigned him several auxiliary workers. Prepared mirrors up to 1 m and more in diameter were transferred to the basement of the workers' club, where they were kept at constant temperature and were polished.

Ergart invited us to see him. The village included small neat cottages with broad windows and flowers. The apartment did not differ in anyway from a city apartment; the walls were painted various colors, there were pictures. Through the window could be /80
seen part of the street extending into the forest.

At the table we had a long conversation about astronomy, space flights, tektites, and on how workers live in the USSR and in Czechoslovakia.

Ergart told how amateur astronomers wanted to begin a major experiment on tektite synthesis and asked my advice. It is difficult to overcome emotion when you get to know such persons.

The weather grew worse. We turned back and passing through Vishshi-Brod and Ceske-Krumlov returned home, tired, but full of impressions.

Several days later we again visited this region and went up Mount Klet' -- the dominant peak of the region, between Ceske-Budejovice and Lipno. On inspecting the new tektite deposits and taluses of large celt rock where Shkrov had thus far fruitlessly attempted to find even one moldavite, we penetrated into the Blanskiy Forest and in an hour our car emerged on the peak itself. Here and there snow was still to be found. A wild heap of rocks. The elevation was 1084 meters. To the south, they said, from here opens up a marvelous panorama of the Shumava and Alps, and to the north -- the valley of the Elba (Labe). But today nothing could be seen: a fog was all around us and only strong gusts of wind reminded us of our elevation. We could see the base of a television tower which enabled us to receive transmissions from Prague, a hotel with a restaurant, and, finally, the observatory -- the branch of the public observatory in Ceske-Budejovice. Saturdays and Sundays, summer and winter its director, Doctor Bogumil Polesni works here and receives tourists. On that day I was his guest.

But we did not always travel by car. Finally, ahead of us was our route. This meant that we could make unhurried entries into our diary, think about the direction of future studies, and take required photographs. The participants in the hike were the following: Shkrov, Zhila -- a teacher from Shumava, Brems, and myself. We passed through all of the tektite-bearing territory from Vrabce to Kvitkovice, continuing our route essentially for the first day.

We began from Nova-Gospoda, where Jan lives. He is now in school, and we very carefully inspected the freshly plowed field. I compared the mineralogical composition of already familiar soils. /81
Only Gustav was lucky: he found two moldavites. And again in the soil there were many Slavic and Celt ceramics, which I still distinguished with difficulty, not on a par with the younger son of Shkrov -- a pupil in "mothers' school" (kindergarten).

Along the route through the pine forest Zhila told about his work: the settlement was a small one, the school also, and students in all classes sat in the same room -- five first-graders, two second-graders, two third-graders, and one fifth-grader. When the teacher read a story to the little child, the other classes also heard it, and when the others had singing lessons -- all joined in.

The forest came to an end. The beautiful panorama of Mount Kluk (in translation "child") opened up before us, and at its base -- the village of Slavce, already known to me and to all who study tektites. We descended into the valley of a small little brook and climbed now through these fields of this village. The search was still unsuccessful, with only Martin finding two small specimens.

A halt. We would have gone several hundred meters further and entered a cafeteria which from old times is here called "gospoda" (tavern). But it was much more pleasant to have breakfast in the forest, by a bonfire, among pine seedlings. There are few virgin forests in South Czechoslovakia, exclude the Shumava. A unique charm of the landscape is produced by the alternation of small tracts of forest. These are plantings with an average history of 50 years, which are systematically renewed and expanded.

From the elevation where Slavce lies extends a broad panorama of tektite-bearing fields, rising on hills, descending into valleys, and concealed by copses. Lipi, Gradce, and Gabrzhi can be easily seen. Inspecting the map, we made an involved comparison of the relative elevation of the locale with how often moldavites are found and how their sizes and shapes change. Nearer the city of Kluk the mineralogical composition of the soil is now of a different kind: more ancient, metamorphic [18] rocks predominate, and there are nearly no tektites.

Beyond a new copse at the forestry preserve Reytinger, named after the family of an entire dynasty of foresters, we attempted to analyze the administrative subdivision of this section -- which fields belong to Slavce, which -- to Gabrzhi, and which -- to /82
Lipi. The literature of tektites is completely confused in this respect, and different authors place the same section in different deposits. The black-currant field on the slope extending from the forest preserve in the direction of Slavce, especially rich in tektites, is one such tract in dispute.

Using the opportunity, we decided to see the forester's daughter Mariya Reytingerova, whose name has entered Soviet scientific literature due to the discovery of an interesting specimen. The girl was not at home. She was studying in an agricultural college in Ceske-Budejovice and was expected to return soon on the scheduled bus. We went to meet her and beyond the gates of the house saw the youngest representative of the family of foresters -- a seven-year-old girl. Gathering all her courage, she conversed with us just like an adult. On departing, already deep into the forest, we suddenly heard the footfall of her feet. Deeply reddened, she extended to us two moldavite specimens. I presented to her an insignia with a space rocket. We were not able to ask her again before Mariya suddenly appeared on the trail. "Oh, how she is grown, she has become really grown up and what a beautiful blue coat she has on!" jokingly exclaimed Shkrov, who had met her several years ago when she had enthusiastically tried to help the youngsters from the astronomy group in their important work of tektite collecting.

For a long time we stood on the hill which opened onto the panorama of Gabrzhi and Lipi, and studied the disposition of the fields and the local terrain. One of the fields was an extensive private holding of a collective farmer and in order to rove across it, Shkrov asked for permission of the owner. The latter proved

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[18] Metamorphic rock is the general name given to modified and recrystallized rock under the effect of high pressures and temperatures.

to be very talkative and told us that for more than 50 years he had been finding tektites here and that he had once given Hanus an enormous specimen together with several kilograms of small tektites.

On making our foot hikes through the fields of South Czechoslovakia, you involuntarily feel yourself to be a footman, for the number of villages produces a distorted idea of how many kilometers you have covered. And even though on the map we had not covered so much, but by the end of the day everyone was tired.

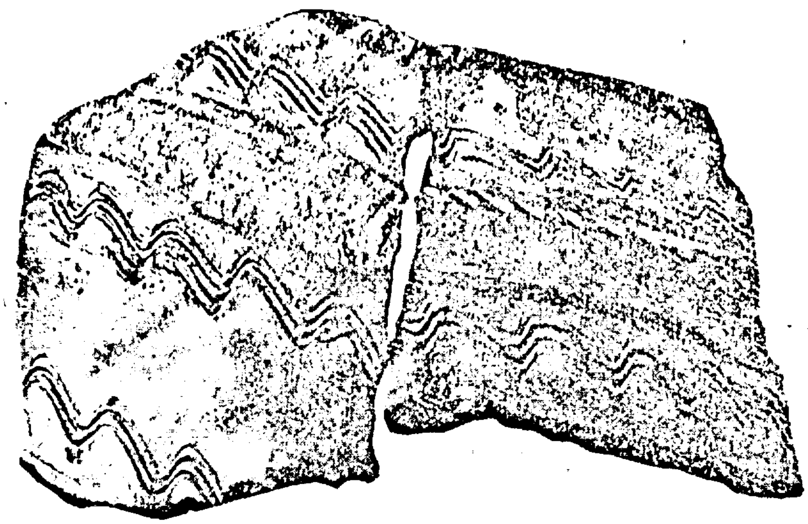

Fig. 33 . Slavic ceramic pieces are often found in the fields together with tektites. Bezdrev (Photograph: G. Shkrov) /83

Fig. 34. Forest Preserve Reytinger

We decided to make a halt in a "gospada", which in the words of Shkrov, had not changed at all since ancient times. A long unpainted table, on one side -- a rod bench, and on the other -- modern chairs. We, guiltily slanting our dirty shoes, cautiously step along a freshly washed floor and take our seats along the table. The host, learning about the aim of our hike, leads us a lecture on moldavites with fascination and also propounds his own hypothesis on their origin. /84

Gabrzhi is a typical South Czech village, with clean and sturdy homes. On many of them we see the dates, 1807, 1837. In a square beside the road is a monument to fellow-villagers who died in the First World War.

The fields of another village and tektite deposits -- Kvitkovice -- begin just at the edge of our present village. To the right beyond a ravine is Lipi.

We headed out toward Prague on a rainy day. A beautiful Tatra-603 hurried us along an asphalt highway.

The city of Sobeslav. Here the authentically known moldavite finds come to an end.

Before reaching Prague, we drove to the Astronomical Institute in order to talk with Doctor Zdenek Ceplekha about the cosmic aspects of the origin of tektites and to examine the observatory.

We devoted in the first half of our day in Prague to the National Museum, whose lovely building crowns, as a palace, Vaclavska Square.

We met the invariably radiant and jovial Doctor Karel Tuchek. All tektite treasures of the museum were uncovered in several hours.

It is not easy to examine 15,000 specimens! You need a system. I developed such a system while inspecting the collections of Prokopets and Oswald: I gave a general glance over the display of one deposit and immediately tried to discover its principal features: typical dimensions, shapes, the state of preservation of the sculpture, and luster. So it was here as well. I worked as an automatic machine, before me hundreds of boxes floated just like frames of a fascinating film.

When the workday came to a close and the exhibition began to be locked up, I rose with difficulty, rubbing my numbed limbs. The staff member who helped me during the inspection was no less tired than I was. But the work had been done. The last entry was now in the book of remarks, with a curious collection of autographs of tektite admirers. Together with Shkrov we thanked Doctor Tuchek and his colleagues, and again before us was Vaclavska Square.

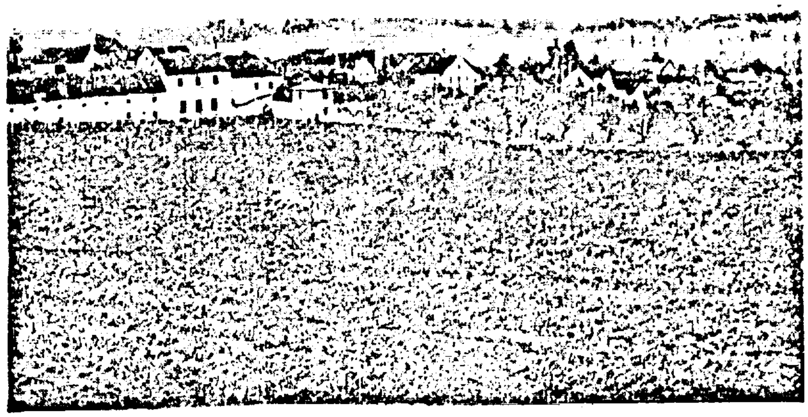

Fig. 35. Gabrzhi /85

Along the road we stopped and went into a jeweler store. "Do you have articles made of vlatavites?" asked Shkrov. "We do, but very infrequently."

Then a visit to Doctor Radim Simon. A jurist by profession, now no longer young, but very lively and expansive in personality.

If Jan Oswald was the past of Czechoslovak science on tektites, Simon was its present. He had been engrossed in tektites for 50 years. He had put forth a great deal of effort in organizing the Czechoslovak service on meteorites and tektites. Thanks to Simon the first national tektite conference were held. Now he is devoting himself fully to the study of moldavites of Moravia, justly regarded as the leading specialist in this field. He has made 30 trips to Moravia, collecting rich scientific material. I have kept a friendly cartoon presented to me by the Czechs: Simon is absorbed /86 in studying a meteorite under the microscope and does not see through the window that another meteorite is flying toward him.

We had corresponded for long time with Doctor Simon, and now we were to meet him. We had much to talk about....

I have told only about the small part of our hikes and meetings. Trips and discussions with the regional geologist, Doctor Yaroslav Kotsian, were of invaluable assistance. Meetings with scientific coworkers of the teachers' institute and the regional museum lifted the curtain of the historic past of South Czech tektites.

In my farewell, I gave several lectures at the observatory.

And now about how the Czechoslovak tektite shower fell, -- all that together with Shkrov we learned and all that was found by our young friends during this time.

Glance at the map of Western Czechoslovakia. Twenty million years ago the geological landscape did not differ very much from what it is today. The same Czech-Modavian Highlands, descending toward the west into the Trzebonsko-Budejovice Basin, to the east -- into the Moravian Depression, and to the north -- into the valley of the Labe (Elba) River. Only the Vltava was not what it is today -- taking its origin in the Shumava, bending sharply from the southeast to the north, merging with the Luznice River and flowing into the Labe.... Much of the Trzebonsko-Budejovice Basin is occupied by a lake into which many small rivers empty. It is how there possible that among them were the pra-Vltava and the pra-Luznice.

The tektite shower fell over the territory equals to several tens of thousands of square kilometers. Today there are two main tektite regions -- South Czech and Moravian, occupying a thousand square kilometers or even somewhat less, each. What happen since that time?

For millions of years the mountain ranges have been weathered and the products of disintegration together with moldavites have been swept into the lowland sections where intensive sedimentation accumulated. One such section is the Trzebonsko-Budejovice Basin containing a lake. Rivers flowing from the Czech-Moravian Highlands and other adjoining mountain areas swept moldavites together with sand and pebbles, depositing them into the lake. The thickness of the bottom deposits grow, and everywhere moldavites became embedded in them, like raisins in cake. Only in the most ancient and quiet corners of the lake where thinner ooze later transformed into clay are there fewer or no moldavites at all. Gradually the bottom was elevated to the extent that the lake dried out. The rivers flowing into the basin needed a new outlet. They joined together, forming a common channel, and found a discharge. Thus /88 was born the present-day Vltava.

A hundred years ago geologists looked for a tektite layer in the rocks and the nature of the moldavites remained for them a mystery. They did not know that such a layer did not exist. Tektites cannot fall in a continuous hail and only their gradual drift into one place led to the formation of tektite-bearing deposits of considerable thickness with the world's record for the number of finds per square kilometer -- several dozens of tektites, on the average, and in some places even several thousands.

During the period of the so-called Alpine orogenic movements, two enormous fractures occurred along the margins of the basin and the interior part of the basin sank, forming a fault. Then, a million years later these scarps became smoothed over, but the sunken section remained unchanged. They were present in the areas beyond the limits of the fault where moldavites were found only in relicts of riverine and lacustrine deposits, or else had been overlain by younger -- quaternary deposits.

Thus, in each deposit the lowest-lying tektite specimens can be "native", that is, having fallen at the locale, while those lying higher up are transported tektites, perhaps from different locations. Oswald, Prokopets, and other local investigators suggested method for recognizing "native" tektites: usually soil is packed into these sculpture elements of specimens, which can be easily washed out. This soil cannot be washed from the underside of "native" specimens -- it sticks "dead burned" from the long recumbence of the specimen or else because the tektite fell while still hot and somewhat baked the ground under it. Thus far this is only a hypothesis, though quite reasonable.

How did the prolonged transport in water currents affect the specimens? Study of collection materials showed that they acquired a more matte luster, became pulverized, the sculpture became smoothed, and in especially unfavorable conditions they were transformed into actual, well-ground pebbles.

When a certain specimen size, specific degree of sculpture preservation, and a specific luster are typical of a deposit, this means that all specimens arrived by the same means of transport.

And, conversely, if the deposit does not have "its face," then all degrees of dimension, grinding, and luster can be found in it. But the group members were able to show for one of the deposits that tektites had arrived here mainly by two means of transport: specimens with well-preserved and poorly-preserved sculpture proved to be more typical than specimens with completely-preserved sculpture, ground, and with identically developed elements of sculpture and grinding. /89

Accordingly, we developed a more penetrating program of further research: all deposits will be evaluated by all features (dimensions, shape, sculpture preservation, and luster) in order to more fully reconstruct the pattern of the geological redistribution of tektite material within the limits of the Czechoslovak strewnfield.

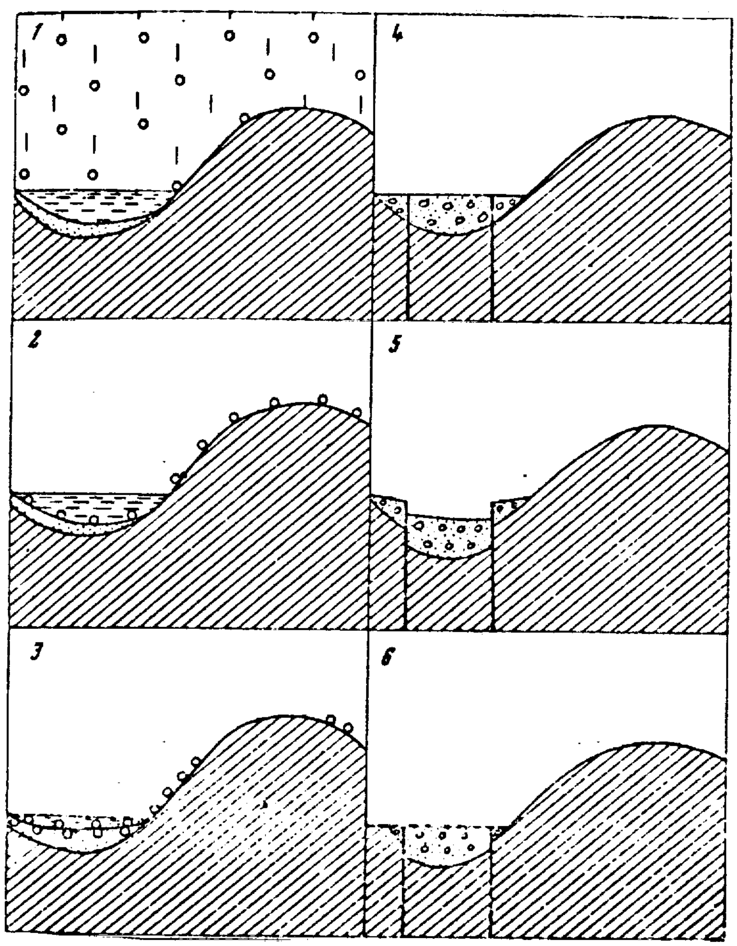

Fig. 36. Scheme of the geological history of moldavites /87

METEORITES? COMETS? MOON?

Cybernetics and Tektites. -- A Planet Crashed to Pieces. -- Tektites -- Earth Satellites. -- Mystery of the Tungus Catastrophe and the Chicago Fire. -- Battle for the Moon. -- On the Night of February Ninth. -- From Glass Shells in the Heavens. -- How Is the Moon Getting Along?

And thus, all tektites evidently are associated with outer space. In each of our chapters we logically reached this conclusion.

Is there a method that will enable us to weigh all "Pro's" and "Con's" and make this conclusion more definite? Yes, there is. It is proposed to us by cybernetics.

Many people believe that cybernetics is only electronics, automation, and computers. But actually, these engineering disciplines are only the tools of cybernetics -- the science of optimal control. And one can never control anything without information. It must be gathered, memorized, retrieved from memory, processed, and transmitted (in living organisms the information is by logical, in computer systems it is numerical, and in libraries and archives it is documentary). But cybernetics is not just any kind of control, but optimal control. The rapid and error-free diagnosis of disease, the execution of the correct processing regime, mass instruction in accordance with the psychological traits of each student, and the acquisition of exhaustive information of any subject -- here are several of the numerous directions in which cybernetics is engaged.

Proceeding to the problem of tektites, we decided to set up the simplest cybernetic library numbering several tens of thousands of pages, capable of fitting in the drawer of a writing table and answering not just two questions (author, subject), as is usual, but more than a hundred questions at once.

The content of each article or book was entered onto a punched card 207 x 147 mm in size: on one side was the abstract (brief contents), and on the other -- a microform of the text up to 40 pages in size. Along the edges of the card are two rows of openings. A specific feature corresponds to each opening or their combination. If the card bears this feature (that is, the given problem is dealt with in the article), the opening is notched -- it opens outward (Fig. 37).

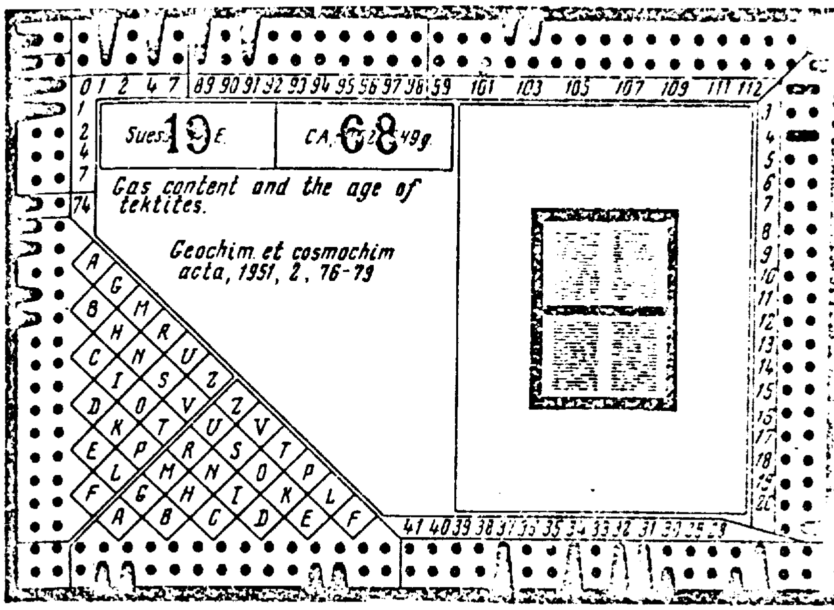

Fig. 37. Punched card from microlibrary on tektites /91

The cards are kept in the card file usually without any order. Let us assume that we need all the literature on australites. We find the corresponding opening on the card, insert an ordinary knitting needle into it so that it passes simultaneously through 200-400 cards. We raise the pack with the needle, and all the cards we need bearing the notches in the required place drop out of the pack, wherever they may be. When we need to answer once two questions (for example, the geography of australites), we use two needles.

The articles are read on the screen of a desk reader.

Thus, all aspects of the problem have been introduced into the bibliographic system: the location of tektite formation (earth, earth satellites, solar system, and so on), possible conditions of formation (flight, fall, explosion, volcanic eruptions, and electrical discharge), the territorial groups of the tektites, their /92
composition, physical properties, and other features.

Then we began collecting the literature: we set up connections with domestic and foreign libraries and individual specialists, check all bibliographic references in the known literature, and scan abstract journals.

It is a very difficult thing to master the entire flow of literature, in spite of the fact that three abstract journals of the All-Union Institute of Scientific and Technical Information (VINITI) -- Astronomiya /Astronomy/, Khimiya /Chemistry/, and Geologiya /Geology/ systematically publish abstracts of articles on tektites. This is what our statistics covering these materials revealed (in percent):

published in three of the abstract journals cited, simultaneously	34
published in two of these journals (the article did not appear in the third journal purely by chance)	25
published in one of these journals	3
arrived at the VINITI, but not abstracted in these journals (accidentally sent to other journals)	2
arrived, bypassing VINITI, into our own correspondence network	17
known to us only by bibliographic references	4
unknown to us	15

If we had wished to read the literature not dealing directly tektites but containing special, but at times important information about them, then the last numerical figure would have to be increased.

In three years we assembled the world's most complete library on tektites, numbering several thousands of books, articles, and notes. Note, incidentally, that this format of punched card micro-libraries was in general the first in our country. Today there are now quite a few such libraries. Upon an analysis of the literature on tektites it was found that its volume is growing exponentially [19], that is, it is doubling every 20 years and is increasing by tenfold every 60 years (Fig. 38). There are only three cases of deviation from this law: 1) in the 1880's-1890's when the cosmic /93

[19] An exponential is a mathematical curve which at the outset is parallel to one of the axes of the plot, and at the end -- to the other axis. If we replace the arithmetic scale on one of the axes with the logarithmic scale, the exponential becomes a straight line.

origin of tektites had not yet been considered as an object of discussion and all other hypotheses began to outlive their time; 2) during the First World War; and 3) during the Second World War. Of course, this law cannot operate indefinitely. Whereas in the beginning of the 20th century about 20 studies on tektites appeared every five years, today more than 200 studies appear, while at the beginning of the 21st century their number must be more than 2000.... The operation of the law will cease as soon as the problem is solved.

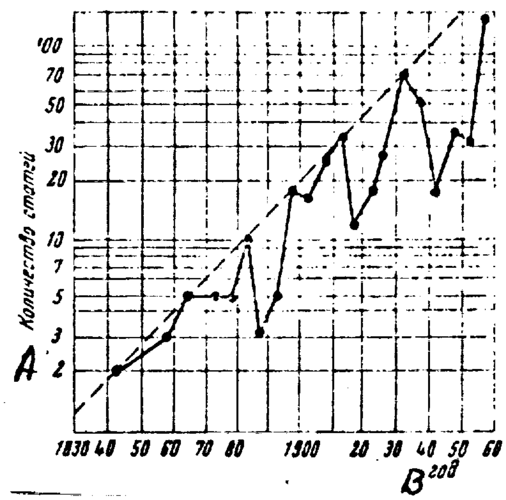

Fig. 38. Exponential growth of tektite literature
KEY: A -- Number of articles
B -- year

Other statistical data are also of interest. Thus, the majority of authors published only one article, that is, they had a chance connection with the problem. One-fourth of these, interested in the problem, wrote a second article, one-eighth -- three articles, one-twelfth -- four articles, and so on. Considerably fewer than 1 percent of all authors systematically work in this field and published ten papers.

Our experience with the punched cardfile and the "combing" of the entire literature with respect to a hundred subject matter areas showed that the majority of facts speak in favor of the cosmic origin of tektites. This was confirmed also by using a Minsk electronic computer.

Let us enumerate the facts whose authenticity raises no doubts.

Tektites are distributed unevenly in the earth and form individual strewnfields up to several thousands of square kilometers in size.

By composition, tektites are not similar to any other rock and are similar to meteorites in a number of features. Within the same strewnfield the composition varies in a directed fashion, in spite /94
of the great diversity of the rocks occurring in these regions.

The age of tektites and the age of intervening rock usually coincide. Evidently, tektites fell on the surface of the earth and were buried by the geological deposits formed. Therefore the frequency of their finds is usually inversely proportional to their age. These falls occurred a number of times.

The melting and formation of original tektite forms occurred before their fall on the earth. During their fall, they were again melted, modified, the original forms were partially broken down, and characteristic surface elements (sculpture) were formed. Further changes (disintegration, corrosion, and leveling of sculpture) now occurred on the earth and are related to purely geological phenomenon.

It remains to be decided which cosmic processes were responsible for tektites. Here we can adopt one of two positions: tektites have nothing in common with the earth or they were formed in the interaction of terrestrial and cosmic processes. Present-day hypotheses have developed along these two directions.

Any scientific hypothesis is a tool proposed for solving a problem. It is not a misfortune if many of them proved to be invalid, but they still would assist the one who has the last word. Today we can speak only of which of the cosmic hypotheses has the most number of confirmed facts in its favor.

Let us look at these hypotheses.

Tektites are a special class of meteorites, parts of disintegrated cosmic bodies. This hypothesis is the oldest cosmic hypothesis; it was advanced even by Suess and Lacroix, and is now being developed by Baker and Koenigswald, Oswald, and other scientists. For many it is an obvious fact, and in the literature we often encounter, along with the term "tektites", its synonyms -- "glassy meteorites" or "meteoritic glass."

Astronomers believe that as the result of the disintegration of one or several planets of the solar system asteroids (small planets) were formed, ranging in size from several hundreds of meters to several kilometers. From time to time we see "falling /95 stars" in the night sky -- meteorites, and less often -- bright large bolides, reaching the earth as meteorites weighing up to many tons. Even smaller bodies are known, which are responsible for the appearance of the so-called zodiacal lights in the night sky. The total mass of the small planets is 10^{-3} of the earth's mass. The mass of meteoritic material is expressed by about the same figure. A well-defined subdivision of meteorites into two classes -- iron and stony -- made it possible to consider the former as fragments of the iron core of planets, and the second as the heavy silicate mantle surrounding the core. From this point of view, it is easy to assume that tektites are formed of the uppermost silicate layer of a planet. Disintegration of a planet leads to the fusion of this core and the transporting of its products in the form of drops and spheres (of the order of several centimeters) or even larger, so-called prototektite bodies (up to 100 m) with secondary melting in the terrestrial atmosphere. Petrochemical analysis of iron meteorites, stony meteorites, and tektites confirm this hypothesis. However, a serious qualification is raised by the fall conditions of these bodies: meteorites fall in regular fashion, but in the form of individual specimens, while tektites fall in showers arriving at certain intervals of time.

Tektites are the products of the explosion of meteorites, af asteroids, or comets at the earth's surface. The founder of the meteoritic impact [20] hypothesis was Spencer, the investigator of Lybian desert glass. In searching for analogies, he studied several meteoritic impactites -- silica-glasses of meteoritic craters, and advanced the hypothesis that tektites also formed during the explosions of giant meteorites on the earth.

In turn, this hypothesis has raised a good many objections. The first is: meteoritic impactites and tektites, given some partial similarity, still differ widely from each other. True, it can be assumed by stretching the point a great deal that these differences are caused by different classes of meteorites: iron meteorites served as the starting-point for all presently known impactites, and stony meteorites -- for tektites.

A second objection is that meteoritic craters are not found in all the regions of tektite distribution. However, geological processes can obliterate such craters, and no one thus far has looked for them in ancient deposits. /96

A third objection is that the formation of tektites during a momentary explosion phenomenon requires exceptional conditions

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[20] Cf. footnote on text page 49 /translation p.43/.

(in particular, high temperatures), and complying with these conditions should have led to the expulsion of the explosion products by a distance exceeding the diameter of the globe and their return in the form of a compact shower seems not highly probable.

This objection rendered the hypothesis most vulnerable and required its radical re-examination. As a result, its advocates gradually moved from the meteoritic version to the asteroidal: tektites were formed in the collision of the earth with asteroids, as the result of which the explosion products became temporary earth satellites and then fell over certain parts of the earth. This scheme increases the probability of the transformation of the initial material into the homogenous glassy state, though the mechanism of this process thus far remains unclear.

Barnes, who published a graphical scheme of the formation of tektites by this means (Fig. 39), is the most enthusiastic advocate of the asteroidal version. He has assigned a specific meteoritic crater for each tektite strewnfield. Craters of unreliable origin have been drawn upon: the Bosumtwi in Ghana -- for the tektites of the Ivory Coast, and Ries-Kassel in the Federal Republic of Germany (in whose territory several inhabited locations are situated) -- for the moldavites. For long time it was not possible to find a suitable crater for the australites. But now geophysicists suddenly discovered it along the magnetic anomaly over the glacial shield in the Antarctic, and in the nearly precisely predicted region (71° S. Lat. and 140° E. Long., Wilkes Land).

There is no doubt that the development of the "satellite" concept in the impact hypothesis was influenced by the scientific event of the launching of artificial earth satellites. For this reason several of my colleagues have joked: When engineering thought signaled its triumph by the construction of the Suez and Panama canals, astronomers suddenly saw the same canal on Mars; now, when numbers of artificial satellites have been launched, the idea of the possible flight of tektites as earth satellites was also "launched".

The comet variant of the impact hypothesis is a special case. Its founder, the astronomer Harold Urey, in counterweight to the view of Spencer, proposed that we consider tektites to be the /98
products of an explosion in the collision of a comet with the earth. This variant did not draw close criticism not because it was more convincing. It is simply that science knows much less about comets

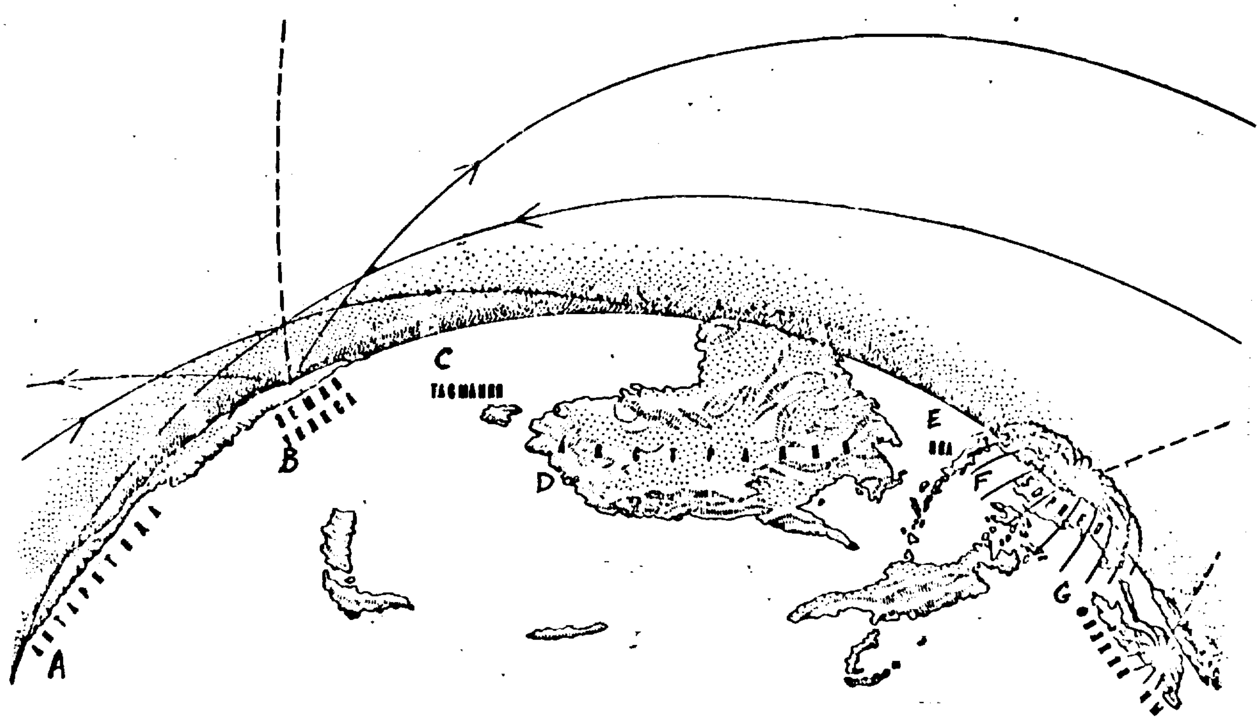

Fig. 39. Scheme of tektite formation during the fall of asteroids to the earth (according to Barnes). The dashed lines are the descent trajectories and the solid lines are the flights of the explosion products /97

KEY: A -- Antarctica
B -- Wilkes Land
C -- Tasmania
D -- Australia
E -- Java
F -- Borneo
G -- Philippine Islands

than about meteorites, and such "fine points" as, for example, whether the ejection of explosion products into an orbit around the earth was necessary for tektites to be formed or not, cannot serve as a basis for the controversy. It is sufficient to state that the origin of comets in general thus far remains unclear.

Usually elements such as a head with a diameter of hundreds of thousands of kilometers, a core several kilometers in diameter, and a tail sometimes as much as hundreds of millions of kilometers in length are differentiated in comets. The mass of a comet is

10^8 - 10^{13} tons. Clumps of frozen gases -- carbon, ammonia, methane, and others, and silicate and iron-nickel particles are present in the core at a density of 0.01 g/cm^3. A comet with a core diameter of 10 km exhibits a kinetic energy of $5 \cdot 10^{28}$ erg at a speed of 40 km/sec and a chemical energy of 10^{27} erg, which causes the explosion reaction over an area of 60-100 km, the melting of rock, and the scattering of explosion products over a wide area. Unfortunately, we do reliably know of a single case of the collision of a comet with the earth, though such cases are entirely possible. If we adopt the hypothesis of Academician V. G. Fesenkov on the comet nature of the famous Tungus catastrophe of 30 June 1908, as a result of which forests were flattened in a radius up to 30 km, the crash of the explosion could be heard up to 1000 km away, and an explosive shock wave encircled the entire globe, and for long time thereafter light nights were observed, then we can get an idea about the nature of such an event. Perhaps, tektites must be sought for in the area of Podkamennaya Tunguska /Stony Tungus/? One would think that the answer is no: There are continuous swamps there and there is an absence of rock.

Recently a fantastic report appeared in the press, raising skepticism among astronomers. A young American scientist, Chamberlain, related another known event -- the Chicago fire of 8 October 1871 to the fall on the earth of the tail of Bailey's Comet. Here the following facts were compared: the approach of the comet to the earth and then the disappearance of its tail (astronomical observations were not made due to poor weather); a meteoritic shower on the night of 27 January 1872; numerous local fires in many states along the Pacific coast; the death of hundreds of persons outside the city limits of Chicago; and by the testimony of eyewitnesses, rock burned like coal in the area of the fire, while metal building slips were fused into monolith, along the river bank. /99

At least, new data are needed on the nature of comets in order to successful develop Urey's variant of the impact hypothesis.

Tektites are the product of meteoritic explosions or volcanic eruptions on the moon. We have already said that the founder of the "lunar" hypothesis was the Dutch scientist Farbeck, postulating in 1897 a 400,000-kilometer path of the products of lunar volcanic eruptions onto the earth. Thirty years later this thought was supported by G. Link and also was without success. In another 20 years, the American H. Nininger, under the influence of atomic blasts in Japan, justified the probability of explosions of this kind on the moon. Almost completely lacking an atmosphere, our only natural satellite is highly vulnerable to meteorites, which according to calculations must explode roughly similar to the size of atomic bombs. The work of Nininger was continued by C. Varsavsky, who proved in 1956 with a high-speed computer the probability of lunar matter falling on the earth in compact swarms, forming scattering ellipses of several thousands of kilometers. Here the following explosion conditions were required: the ejection of products at an angle of $15-20^{\circ}$ to the lunar horizon and an initial velocity of not more than 2.5 km/sec. But Varsavsky also indicated a point in the middle of the eastern hemisphere of the moon as the source of the Australian tektite strewnfield. But this scientific sensation still did not make an impression on his contemporaries. It was not believed that the earth and the moon have an intimate "material" bond. Recall the disbelief 150 years ago when the problem of the possibility of cosmic matter in general falling on the earth was resolved.

But the "battle" for the moon continued. The most energetic and persistent advocate of the lunar hypothesis became the American J. O'Keefe, who published, beginning in 1959, a series of articles on the subject. He developed a scheme for the transport mechanism /100
of lunar material along spiral orbits in the form of compact swarms, dispersing during their deceleration in the earth's atmosphere the small entry angle (5°) made tektites temporary satellites executing half an orbit or more around the earth (Fig. 40). If this mechanism were realistic, naturally one would ask whether astronomers had seen such events. O'Keefe vigorously took on the exploration and soon encountered a phenomenon which had once amazed the scientific world, but has been rapidly forgotten, just like all other similar phenomena for which the appropriate interpretation cannot be given. I refer to the event occurring on 9 February 1913 and called, by the day Saint Kirill, the Kirillid stream. This stream was observed by many inhabitants of the North American continent and coterminous regions (Fig. 41). Here is what the now-prospering Canadian astronomer C. Hunt wrote about it: "About 9:05 in the evening suddenly a fire-red body appeared in the northwest area of the sky, rapidly approaching and growing in magnitude; sometime later a long tail appeared behind it.... The streaming tail was of the same color as the head, which gave the impression of the flight of a rocket; but in contrast to a rocket, the body did not reveal an attraction toward the earth. It moved strangely ahead along a completely horizontal line -- majestically and leisurely, continuing to travel along this course without visible descent toward the earth and, on reaching the southeast region, quietly disappeared in the distance.

.... Scarcely had the amazement caused by the first meteor passed, when other bodies appeared in the very same place in the northwest. They also moved along the same leisurely route, in a pair, by threes and fours, with tails extended behind them, but as bright as in the first case. They all intersected at the same point in the southeast section of the sky.... After the disappearance of these bodies in many cases a roaring could be heard distinctly, similar to far-off thunder or the noise of a formation of men travelling over an uneven road or over a bridge. In several cases three such sounds were heard, made at short intervals. Large number of people felt the earth or their homes to tremble.... The total duration of this phenomenon was not determined very precisely and was evidently 3.3 minutes."

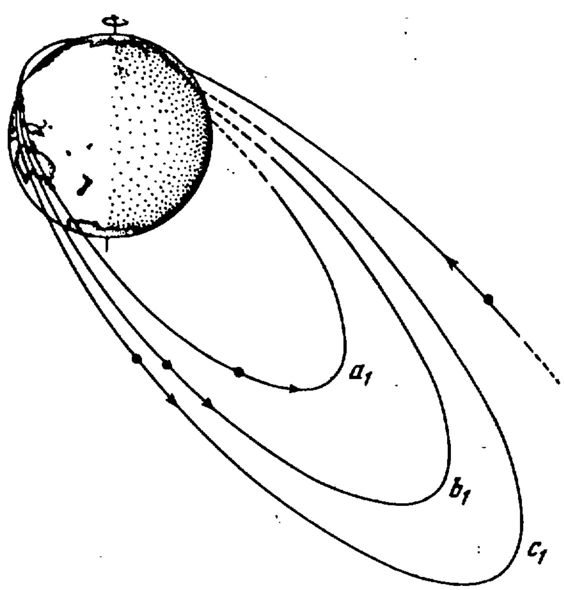

Fig. 40. Terrestrial orbits of the products of lunar explosions (after O'Keefe) /101

Even if the Kirillids were not tektites, this phenomenon convincingly points to the possibility of orbital flights around the earth and tektites. Typically, in particular, the orbit of the Kirillids passed for the most part over unpopulated areas (the Arctic, the Atlantic area, and the Antarctica), with the exception of Canada, the United States, and the Caribbean, where they were seen by many. Therefore it can be concluded that the duration of their flight was at most one orbit, and at least half an orbit, which also agrees with O'Keefe's theory.

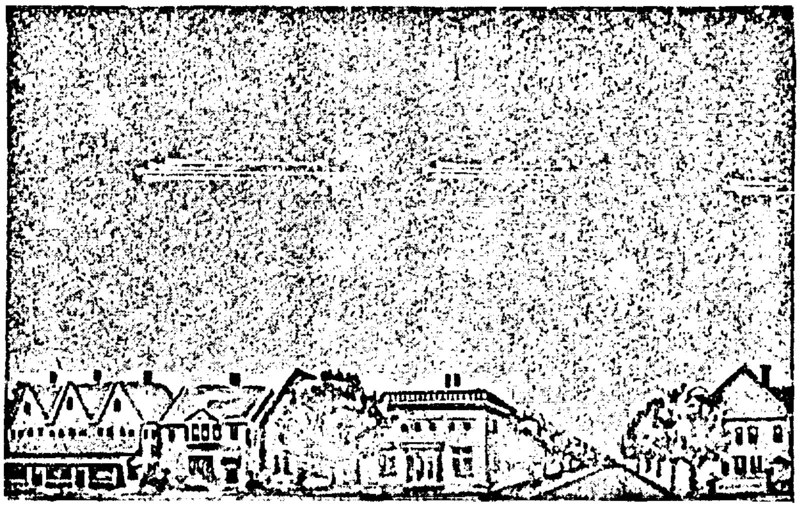

Fig. 41. Kirillid stream /102

This theory attracted many investigators, not only astronomers, and at the present time a search for tektites has been organized along the route of the flight. Collectors of the US Geological Service are undergoing special training. Special instructions are being published in large quantities.

Further studies yielded new data in favor of the idea of O'Keefe and the lunar hypothesis as a whole. The US National Aeronautics and Space Administration organized a series of experiments on the aerodynamics of glassy bodies, establishing that the shape of tektites depends on the conditions of their entry into the earth's atmosphere: at an entry velocity of 10-13 km/sec and an entry angle of 6-7° to the horizon. Comparing these data with the data of the Australian Baker on tektite morphology, one can conclude that initially the tektites were in the form of hollow spheres, which on moving into the atmosphere underwent so-called ablation: the material over the frontal surface melted and travelled to the rear, with partial vaporization; as a result, charac- /103
teristic waves appeared on the sphere, and then the equatorial edging -- a flange (Baker called these forms -- "scoop of ice-cream"); the continuation of this process led to the thickening of

the sphere and its conversion into a button. Under other conditions the spheres can become drawn out, converted into cores, and then into dumbbells, and in the break-up of the latter -- into drops and bulbs. The presence of internal cavities and the small entry angle considerably reduced the ablation of tektites, which otherwise would have been completely vaporized in the atmosphere. Incidentally, this discovery had a strong effect not only on the development of the "lunar", but also the "terrestrial" impactite hypothesis.

At the same time, Farbeck's volcanic variant arose within the frame of reference of the first hypothesis. On studying photographs of the back side of the moon, scientists established key differences in the selenography [21] of both hemispheres. In particular, craters are more developed on the side facing us. Two explanations are more plausible: the meteoritic and the volcanic. We have already noted that explosive phenomenon on the moon must exhibit vastly greater force than in terrestrial conditions. But how then can one explain that the sizes of craters on both hemispheres differ? Meteorites must strike the moon from all sides. Volcanologists have given an interesting answer to this: craters are traces of volcanic eruptions, which due to the gravitational force of the earth were more intense on the side facing us. But if tektites are the lava of lunar vocanoes, then why does it differ from terrestrial lava and why did the natural attenuation of lunar volcanic processes not lead to the attenuation of tektite falls on the earth? The first question can be answered as follows: It is not binding that the moon corresponds to the earth in its composition. Answering the second question is more difficult.

Even though certain changes on the lunar surface are still occurring, it is not always clear whether they are of meteoritic or volcanic origin. Here is what the British astronomer F. Thorton writes: "On the night of 19 October 1945 I observed the interior section of the Plato Crater in which whitish patches were observed for a certain illumination. At 23 hours, 24 minutes, 5 seconds, I /104
detected a flash of light resembling a hand-grenade explosion seen from a distance of several kilometers. The color of the flash was orange-yellow. The phenomenon occurred approximately at the distances of one kilometer from the margin of the western ridge.

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[21] Selenography is a division of astronomy studying the nature of the lunar surface (geography fulfills a similar function for the earth).

Obviously, a meteor had hit here, namely from the Orionid shower that had been in flight. The fact that the explosion was observable in practically air-less space made it possible to explain the phenomenon as the descent of a meteor on solid rock, followed by an actual explosion." Much earlier, in 1866 astronomers observed a white-gray cloud in the Linneus Crater (Sea of Serenity), after which the crater margins were found to be levelled. In 1904 a funnel 3-4 km wide appeared in the Plato Crater already referred to; After some time the funnel was covered by a shadow, disappearing in 20 days. And, finally, on the night of 3-4 November 1958 Soviet scientist N. A. Kozyrev detected with a spectrograph the issuing of gases from the Alphonse Crater and determined their composition. On making successive photographs of the suspicious section, Kozyrev was able to fix the beginning of a volcanic (?) explosion. In November-December 1961 he observed a similar phenomenon in the Aristarchus Crater.

If tektites are actually lunar material, then perhaps it can be said that our satellite or its outer section is an enormous tektite? Evidently, not. Various methods of measuring the physical properties of the lunar surface, including also comparative radar data and the dielectric constant for tektites indicate that the moon is covered by some pulverized material [22] with a low degree of compaction. Some believed that this is cosmic dust which has reached the lunar surface unimpeded and has covered it in a thick layer. In the view of others, this layer constitutes explosion products of meteorites or volcanic eruptions. In any case, if tektites were formed on the moon, the lunar material could have served only as a basis for the composition and the structure of tektites.

Summing up all of the foregoing, it must be noted that given the indisputability of cosmic theories as a whole, none of them can pretend to exclusiveness, and if the lunar hypothesis appears to us more reliable, then even here we are dealing with a problem in which there are many unknowns.

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[22] This view was confirmed by the first television photographs of the lunar surface.

CONTINUATION FOLLOWS /105

It seems that I have answered all possible questions, except for one: Do we have any tektites in the USSR? Unfortunately, they have thus far not been found in our country. Why is it that such an enormous country as ours is a blank spot in this respect? Perhaps, tektite showers bypassed its territory? Scarcely. It appears to us that the reason is this: sparse population pattern, dense vegetative cover, and geological sediments reliably conceal from us these wondrous glasses. Recall that even in the United States they were found only quite recently and then completely by chance.

You say: What then is the probability that on finding a tektite along the edge of a road or on beach amidst many other rocks you will give any attention and will not assume it to be of ordinary bottle glass? Are you convinced that you now would show it to a specialist in geology and he, without reflecting, would thank you for the find of the first Soviet tektite? Probably, not so.

Several years ago I published three popular articles in the journals Nauka i Zhizn' and Yunyy Tekhnik. I attempted to briefly recount the amazing features of tektites and to invite all nature-lovers to search for them in their area. Letters began coming in at once. Some wrote that they had already found tektites in their backyard, outside the city, and in the village, and asked what should they do with them? Others recalled their distant childhood and recounted in detail all of the principal and secondary facts of their finds. In their words, "tektites" were blue and red, glassy and crystalline, about the size of a pea, or a large boulder. One of the letters reported that Caucasian mountaineers used tektites in shaving -- they are that sharp. Some sent in their specimens, which proved to be pieces of bottles, metallurgical slag, and quartz.

I must admit that I did not know what to do with these unlucky /106 correspondents! But I have done something wrong here.

Recently together with a group of geologists we made a trip through Turkmenia under the hot November sun. The dry rocky steppe with the thorny tumbleweed, the endless, like a sea, Kara-Kumy with the flattened sand waves, dead like lunar craters, takyrs, and the horrible huffing of mud cones. "Here is where it would be easy to work as tektite prospectors!" thought I. Everything like the palm of your hand. Tektites could have fallen yesterday or many many years ago, but they still would be laying out in the open.

"Let us say, for example," I cautiously addressed a young local geologist who had accompanied the group and who had tried his very best to dazzle us with Turkmenian beauties, "you somewhere encountered green or black glass of irregular shape?"

"You are speaking of tektites? No, I have not found any."

"But do many of your geologists know of their existence?"

"About ten-twenty percent.... Those who read the magazine Nauka i Zhizn' ...."

I am finishing the last pages and I look up at the calendar. Tomorrow a new task awaits me: preparations for the 20th International Congress on Theoretical and Applied Chemistry. A special meeting will be devoted to tektites in the cosmic chemistry section. Soviet, American, Australian, and German scientists will gather. V. Barnes will arrive from a major tektite expedition along the Ivory Coast, Ghana, Thailand, Indonesia, and the Philippines. New discussions will begin.

The mystery of tektites has not yet been solved....

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